EXPERIMENTS

ON

BLEACHING.

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Των γαρ οντων αγαθων και καλων ουδεν, ανευ πονου και επιμελειας θεοι διδοασιν ανθρωποις. Prod. de Hercul.

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ADVERTISEMENT.

At the deſire of the Honourable Board of Truſtees for the improvement of fiſheries and manufactures in *North Britain*, the following treatiſe was compoſed, read in different lectures, and the experiments, ſo far as it was poſſible, were performed before the bleachers of this country. It is now publiſhed in conſequence of a petition preſented by the bleachers to the Honourable Board of Truſtees.

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EXPERIMENTS

ON

BLEACHING.

PART I.

SECT. I.

Connection of chymiſtry with the arts.

MANUFACTURES are to a country, what aliment is to the human body. They ſupply all waſtes; hinder a nation from preying on itſelf; give it vigour for neceſſary duties; diffuſe the look of health and happineſs over its face; and lay up a ſtore of ſtrength for extraordinary exertions of its power. A wiſe government will no more neglect, or overlook the manufactures of a country, than a wiſe phyſician the diet of one committed to his care.

LET us take a curſory view of the different methods neceſſary to be employed in eſtabliſhing manufactures; for without all, or moſt of thoſe, it is in vain to expect that theſe will ever arrive at any degree of perfection.

WE may reduce all the different ways made uſe of to promote manufactures, to two general ſources; the wiſe regulations of the government, and the united efforts of the people where theſe manufactures are eſtabliſhed.

THE influence of the government conſiſts in encouraging home manufactures, by granting protection, privileges, immunities, and bounties, to ſuch as carry them on; by taking off all duties on the materials uſed in them; by eſtabliſhing proper truſtees to have the inſpection of them, and companies with ſuitable privileges; by ſettling proper funds to be diſtributed in rewards to thoſe who excel; by not making it too burthenſome and expenſive for the manufacturers to obtain

obtain good laws; and by a proper regulation of the fashions at their source.

But all these advantages are of small avail, if a ready market is not opened: for it is an axiom in trade, That manufactures increase only in proportion to the demand for them. Here then will the wise politician be again discovered, in discouraging all foreign manufactures of the same kind, by prohibitions, or high duties equivalent to them.

Thanks to the present government for their great regard and attention to the manufactures of *North Britain*. More has been done for it in this way, within these few years, than in all those ages which went before. In after times it will be the distinguishing character of the present, That manufactures and industry were encouraged in *North Britain*, nay, introduced into its remotest parts. What advantage this will be to *South Britain*, is evident to one who considers, that the greatest part of our gains must at last centre there; and that as much linen was manufactured, even in the confusion of the year 1745, as in any of the preceding. This fact merits the utmost attention; and shows, that there is not a more proper and effectual antidote against rebellion, than industry and manufactures.

It is not enough that a government makes wise regulations. The leading people of a country must lend their united assistance. From them alone a true spirit takes its rise, and diffuses itself by degrees over the generality of a country. The lower ranks of people are capable of following, though not made for leading. To discover the good effects of a general spirit in people of rank, let us cast our eyes on a neighbouring island. What well-judged regulations with regard to the whole progress of the linen manufacture! what attention and encouragement to every useful project! what union and spirit in carrying it into execution! what a judicious distribution of public and private bounties! what a wise institution is their linen-hall in *Dublin*, in affording a constant market for foreign merchants, and a conſtant check to the frauds of private dealers! To their eternal honour be it ſaid, no nation ever made a better uſe of ſo bad a commonalty.

They turn even the vices of their nation to the public benefit. Their foundling-hoſpital, erected for the reception of thoſe children, whom parents either cannot maintain, or do not chuſe to own, is become a ſeminary of induſtry. Of 1500 children, thoſe who are capable from their age, are employed chiefly in ſpinning flax and wool. I had the pleaſure lately to ſee 150 girls, between ſix and twelve years old, ſpinning with both hands. A *Scots* woman employed to teach them, has a ſalary of *L.* 30 a-year ſettled on her by the truſtees. It is no difficult matter to foreſee what great advantage this hoſpital will be to that nation in a few years. Theſe children, when grown up, will ſpread themſelves over the country, teach others, double the quantity of yarn, reduce its price, and put it in their power to underſel others. Such a wiſe regulation in this country, would be the means of ſaving

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the lives of many innocent children, and many unhappy mothers, and turn to ſome national advantage what we cannot perhaps altogether reſtrain.

I ſhould be guilty of an injuſtice to this country, were I not in a public manner to own the many obligations which we lie under to the Honourable board for the improvement of fiſheries and manufactures in *Scotland*. Theſe gentlemen, ſince they were firſt conſtituted in the year 1727, have, with unwearied and diſintereſted zeal, contributed in a very great meaſure to raiſe, and direct a ſpirit of induſtry among us, by their own example; by their experience; by adopting the experience of our neighbours; and by diſtributing, with great prudence, thoſe ſmall funds intruſted by the government to their management. For their reward they ſhare the bleſſings of the induſtrious poor.

The great advantage of the linen manufacture, in which point it is allowed to have the preference to the woollen, ariſes from the

the many changes which that commodity undergoes, before it comes to market; and consequently its employing many hands. But this advantage makes it more liable to suffer from ignorance, or fraud; and makes it require more care. There is no part of the manufacture on which its character so much depends, as on its management in the bleachfield. On that circumstance depend its two essential qualities, colour and strength. Of such consequence to the linen trade is that part of its progress, that I may safely venture to affirm, without assuming any title to the spirit of prophecy, that the linen manufacture of *Ireland*, from this cause alone, will, nay perhaps has already, come into some disrepute; and must at last suffer, if the *Irish* do not alter their method of bleaching.

We, in this country, have generally followed a better method; but as that seems to be owing to our vicinity to *Holland*, and not to a greater knowledge in the art, we can claim no merit from it. That an art so ingenious, so difficult, depending so much

much on a nice judgment, conſiſting of ſo many different parts, and withal of ſuch moment to theſe nations, ſhould have lain ſo long neglected, affords matter of ſurpriſe. Thoſe bred to this art are capable of furniſhing materials, but are incapable, as it would ſeem, of reducing it to certain fixed principles. Some knowledge, beſides what the art gives, appears neceſſary even to the art itſelf. This opens another ſource for the improvement of manufactures, *viz.* the conſideration of thoſe whoſe genius or education has led them to the ſtudy of ſciences and arts, on which theſe manufactures, in a great meaſure, depend. There is no art of ſuch extenſive uſe as chymiſtry.

If chymiſtry was once too wild and extravagant, it has been for many years too tame and confined. It ſeldom ventures further than the compoſition of a medicine, as if that were all the ſervice it could be of to mankind. But chymiſtry is of much greatter extent. It claims as its own, all changes that are carried on by fire, or diſſolvents; it looks upon the operators, as entirely under

der its guidance; the operations to be accounted for only on its principles; and the hopes of further perfection in the art, ſo far as human judgment is concerned, to reſt on it alone. This, and nothing leſs, is true chymiſtry; and may be called *Chemia philoſophica*, or *Philoſophical chymiſtry*, as *Boyle* has termed it; or *Univerſal chymiſtry*, to uſe Dr *Shaw*'s expreſſion, in diſtinction to the confined medical chymiſtry.

All arts, excepting thoſe which regard the operations of the mind, may be diſtinguiſhed into mechanical, chymical, or thoſe which partake of both. The mechanical, or ſuch as attain their ends by mechanical inſtruments, are few in reſpect of the chymical, which depend on fire and diſſolvents. In the latter claſs, I rank cookery, tanning, dying, ſmelting, gilding, ſugar-refining, confectionery, baking, brewing, making of ſalt, fermenting of wines and vinegar, the different metallurgic trades, diſtilling, ſoldering, making of ſtarch, glaſs, delf ware, china ware, *&c.* The mixed arts, which partake ſomewhat of each, are, agriculture, building, printing, making of mirrors, paper, &c.

Let us take a view of the dependence which theſe arts have on chymiſtry. Dying cannot be carried on without it. The inſtruments with which that art works, are, quick-lime, alkaline and acid ſalts, ſolutions of tin and iron in acids, and neutral ſalts, as alum, ſal ammoniac, and tartarus vitriolatus. Without the aſſiſtance of theſe ſalts, very few colours can be ſtruck on either woollen, linen, or cotton; but with their aſſiſtance, all the colouring particles are ſeparated from the water in which they are diſſolved, and fixed on the ſurface of theſe bodies. The durableneſs of colours, and their reſiſtance againſt the effects of ſun and moiſture, are to be explained only from the properties of theſe ſalts. In the ſolutions and mixtures of chymiſtry, many beautiful colours, which were never heard of in the art of dying, ariſe, are changed, or deſtroyed.

The art of tanning is a regular chymical proceſs, procefs, not to be underftood by thofe who are ignorant of its principles. What account can the tanner give of his firft operation, fteeping the hides in lime and water? The chymift will inform him, that the intention of it is not only to take off the hair, but to diffolve the oleaginous particles by the affiftance of lime, that fo the paffages may be cleared for the next operation. The former muft be at as great a lofs to give a reafon why he fteeps his hides in water impregnated with oak bark, if the latter did not ftep in to his affiftance, and fhow him, that the infufion of bark, by means of its aftringent falt, diffolved by the water, hardens the animal fibres, and fhuts up all their pores, fo that water cannot pafs through them fo eafily as it did before. It is he alone who can account for the different effects of the different methods of operating in making foft, bend or fhamoy leather.

The cook, while he prepares a difh of foup, is in that fituation a real chymift. He operates with the fame agents the chymift operates with; fire, and the diffolvent or menſtruum water; and with the ſame deſign, to diſſolve ſome part of the meat, and impregnate the water or diſſolvent with theſe particles: but being ignorant of the other branches of chymiſtry, he does not know what parts are diſſolved by the water, how theſe parts are compounded, in what manner they may be ſeparated in greater quantity, or how the whole fibrous parts, nay the bones themſelves, may be diſſolved into a liquor. One who joined this knowledge to his practice, would certainly be a more compleat cook than what he was before.

Agriculture, again, is greatly indebted to the powers of mechanics, the plough, harrow, and other inſtruments, for opening and pulveriſing the ground, in order that the plants may be able to puſh their roots to a greater diſtance, that they may take in their food. But what is that food and nouriſhment which is abſorbed by the roots of plants, and without which it is in vain for them to extend their roots? That queſtion I may ſafely venture to affirm is only to be

anſwered

anſwered by a chymiſt. It is he alone who can ſhow the nature and properties of that vegetable food; it is he alone who can tell how it comes there naturally. Experience indeed has learned farmers, that certain ſubſtances fructify the ground: but he, undoubtedly, will be able to produce the greateſt quantity of that food in the ſhorteſt time, who knows what it is, and how produced. So true this is, that though dung is the moſt common compoſt, and has been uſed in all ages; yet I may venture to affirm, that the chymiſt could teach the farmer many uſeful obſervations with reſpect to the management of dunghills. Farming can never be reduced to a regular art, till a farmer ariſe acquainted with chymiſtry.

I know no trade which is ſo entirely the object of chymiſtry as bleaching, and none that has been ſo little conſidered in that light. For what are ſteeping, bucking, ſouring, waſhing with ſoap, alternate wetting and drying, but ſo many proceſſes, that are carried on by theſe powerful chymical agents, heat and diſſolvents? What is the

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end propoſed, but the diſſolving and carrying off, by the means of acid and alkaline ſals, moſt powerful menſtruums, ſomewhat which gives the cloth its preſent colour? and what way more certain to carry off whatever is looſened, than the evaporation of water by heat, which is a ſpecies of diſtillation performed in the open air?

I find the moſt ſkilful bleachers underſtand the general theory of their art tolerably well; but being ignorant of the principles of chymiſtry, cannot make the proper uſe of this theory, or apply their knowledge to the advancement of their art. They know that alkaline ſalts diſſolve oils, and that a fermentation is carried on by ſteeping, bucking, and ſouring; but chymiſtry can alone teach them, that by certain methods fermentations may either be quickened, and a great deal of time ſaved; or be checked, and much time loſt; nay, perhaps the effect not produced.

But what the bleachers are moſt deficient in, is a knowledge of the nature and

properties

properties of thoſe alkaline ſalts, or aſhes, as they call them, which they make uſe of. Experience has taught them, that theſe ſalts are to be uſed in different proportions; but nothing leſs than a chymical inquiry can diſcover their hidden nature. If this point was once aſcertained, the theory of bleaching would reſt on a more certain foundation than at preſent. For what certain theory can be eſtabliſhed with regard to the operation of thoſe aſhes, when we know not what thoſe aſhes are?

But this is not all the advantage we expect to reap from an examination of this kind. What if theſe bodies are not ſimple alkaline ſalts? For ought we know they may not, but may be a compoſition of different ſubſtances. And what if we diſcover by chymical experiments their compoſition? If this happens to be the caſe, we may perhaps be able to make theſe aſhes at a much cheaper rate in our own country, than what they coſt us when imported from abroad. The inquiry is worthy of the utmoſt attention; and if ſucceſsful, cannot fail to be of

great

great importance to this country. It coſts, as I am told, *Great Britain* and *Ireland* *L*. 300,000 for aſhes every year. It is difficult to ſay to what a ſum that commodity may amount; nay, it is impoſſible to aſſure ourſelves, that we will procure it at any price, when we are told, that the aſhes were monopolized by two *Dutch* merchants three years ago, and retailed again to us at a double or triple price. Our manufactures could not have ſubſiſted during the late war with *Spain*, unleſs an order of the King and council had paſſed, allowing the importation of *Spaniſh* pot-aſhes. Both profit and neceſſity contribute to quicken our induſtry.

For the benefit of the linen manufacture of this country, and of our neighbouring iſland, whoſe intereſts appear to be the ſame, and ought always to be united againſt their common competitors in trade, I have applied what little knowledge I have in chymiſtry, and endeavoured to reduce the art of bleaching, hitherto variable and unſafe, to ſome fixed principles, that it might not depend

depend on opinion, or on ſuch experience as always dies with the poſſeſſors.

Were I to make myſelf acquainted with an art of which I was before entirely ignorant, I would naturally inquire into the common practice, or general method of operating in that art; and then endeavour to diſcover the deſign and reaſon of each operation, that I might know, whether the method generally practiſed was the fitteſt to attain the end propoſed. I would certainly endeavour to get a thorough knowledge of the agents or inſtruments made uſe of in the art; what was the beſt way of procuring or making them at home; and what were their effects when applied in the manner that the art directs. I ſhould at laſt conſider the impediments which the art meets with, and the methods of removing them. This is the plan of the following diſquiſition. I have begun with the general methods of bleaching, and deſcribed thoſe moſt approved of. An examination into each particular operation, its effects, the end propoſed, and the beſt methods of accompliſh-ing it, follows. The nature and compoſition of the different aſhes uſed in bleaching; the method by which theſe ſalts may be made as good at home as thoſe imported from abroad; and their natural effects, when applied to cloth, ſucceed. At laſt is conſidered that great impediment to bleaching, hard water; the method how the greateſt degrees of it may be corrected, is ſhown; and, which is more uſeful to the bleacher, how the ſmalleſt degrees of it may be diſcovered, and ſo ſhunned. I have endeavoured to render the whole as uſeful to our linen trade as poſſible.

There is no way to promote the art of bleaching, which is entirely carried on by the operation of different bodies, but that of experiment: and that alone I have followed. Every other method of advancing the arts is now juſtly derided. It is indeed laborious to the undertaker, and cannot be accompliſhed without accuracy and length of time; it is often unpleaſant to the reader. But, as the former has not deterred me from making the experiments, the latter ſhall not

not hinder me from narrating them as they were made. No doubt can remain when the experiment is before our eyes. I expect this of others; and, therefore, ſhall follow it myſelf.

An attempt to reduce to a regular ſyſtem, an art, in which nothing has yet appeared in any language, in which we have even no account of the common practice, muſt meet with ſome indulgence as to its faults. Curioſity firſt led me to paſs ſome vacant hours in a bleachfield; and the deſire of making bleaching as certain and regular as other arts, puſhed me on. If the ſyſtem is not entirely compleat, I have afforded, I hope, facts and experiments, which will ſerve as a foundation for ſuch a ſuperſtructure. *Hippocrates*, an author equally admired for his art and eloquence, has long ago obſerved, "* That the deſign "and labour of ſcience, ought to centre "in diſcovering what is yet unknown, and

* Εμοι δε το μεν τι των μη ευρημενων εξευρισκειν, ὅ τι και ευρεθεν κρεσσον ἢ ανεξευρετον ξυνεσιος δοκει επιθυμημα τε και εργον ειναι. Δε το τα ημιεργα ες τελος εξεργαζεσθαι ωσαυτως. ΙΠΠΟΚΡΑΤΟΥΣ περι τεχνης.

"may become, when known, uſeful to ſo-"ciety; and likewiſe in completing what "was left by others imperfect."

SECT. II.

On the different methods of bleaching.

THERE is but one certain way to bring any art or ſcience to perfection; and that is, to give an exact detail of every incident which happens in the courſe of practice, and of every change brought about by the application of the agents or inſtruments employed in the art. It is by the hiſtory of diſeaſes and practical caſes, that medicine has arrived to its preſent height. It is from particular ſtatutes and deciſions, that the preſent ſyſtem of law has been compiled. It is from a continuation of this plan, that perfection in theſe ſciences, ſo far as human affairs can attain, is only to be hoped: for on theſe facts alone that theory, which opens a view of the whole art, can be eſtabliſhed.

It is not ſurpriſing, then, that the art of bleaching is ſo imperfect. For what advances could be hoped for in an art, where there was no exact detail of the facts and circumſtances, and where every thing remained a ſecret? It is rather ſurpriſing, that the art has not gone backwards, and been, ere this time, loſt, as has already happened to ſeveral arts for want of a proper hiſtory of them. That ſuch a fate may never happen to this art; that thoſe who are not well acquainted with the practice, may underſtand what follows; that we may have the whole proceſs before our eyes at once, and be able to divide it into its different parts, I ſhall endeavour to trace the great outlines of this art, and ſhow the different methods uſed to bring cloth to its proper degree of whiteneſs.

It was, no doubt, ſoon diſcovered, that the ſun and dews, or frequent watering, were capable, in hot climates, of whitening cloth. This was certainly the moſt ancient practice; and is ſtill uſed, as I have been told, in the *Eaſt Indies*. But colder and

and more variable climates were obliged to ſubſtitute ſomewhat in the place of the heat which they wanted. Hence the uſe of ſalts in bleaching. Chance no doubt made the firſt diſcovery; but when or where theſe were firſt uſed, hiſtory is ſilent. Their uſe began probably in ſome of our northern countries. The cloth would at firſt be boiled in a lixive of alkaline ſalts, and then expoſed to the influence of the ſun and dews. This method is ſtill uſed in the bleaching of yarn, and coarſe open cloths. But in this climate it is very tedious. I tried the experiment laſt ſummer with ſome coarſe cloth; but after it had been boiled once in a lixive, laid out wet, and expoſed for four months, it had not attained even to a tolerable degree of whiteneſs. The ſummer indeed was unfavourable for the experiment, as there was much rain and little warmth. But from what I ſaw, I ſhould deſpair of ever drawing any advantage from this method.

The two methods of bleaching, eſtabliſhed by a general practice, are the *Dutch*, and the

the *Irish*; one or other is followed at present by every bleacher. A description of each of these, is then a description of the whole practice. The *Dutch* method is that most followed for fine cloth by the skilful bleachers; while, for cheapness, they use, in the whitening of coarse cloth, the *Irish* method, or one very like it. I shall then give a short description of the facts which happen in each. The *Dutch* method is as follows.

After the cloth has been sorted into parcels of an equal fineness, as near as can be judged, they are latched, linked, and then steeped. Steeping is the first operation which the cloth undergoes, and is performed in this manner. The linens are folded up, each piece distinct, and laid in a large wooden vessel; into which is thrown, blood-warm, a sufficient quantity of water, or equal parts of water and lye, which has been used to white cloth only, or water with rye meal or bran mixed with it, till the whole is thoroughly wet, and the liquor rises over all. Then a cover of wood is laid

over

over the cloth, and that cover is ſecured with a poſt betwixt the boards and the joiſting, to prevent the cloth from riſing during the fermentation which enſues. About ſix hours after the cloth has been ſteeped in warm water, and about twelve in cold, bubbles of air ariſe, a pellicle is formed on the ſurface of the liquor, and the cloth ſwells when it is not preſſed down. This inteſtine motion continues from thirty-ſix to forty-eight hours, according to the warmth of the weather; about which time the pellicle or ſcum begins to fall to the bottom. Before this precipitation happens, the cloth muſt be taken out; and the proper time for taking it out, is when no more air-bubbles ariſe. This is allowed to be the juſteſt guide by the moſt experienced bleachers.

The cloth is then taken out, well rinſed, diſpoſed regularly by the ſelvage, and waſhed in the put-mill to carry off the looſe duſt. After this it is ſpread on the field to dry: when thoroughly dried, it is ready for bucking; which is the ſecond operation.

Bucking, or the application of ſalts, is performed in this manner. The firſt or mother lye is made in a copper, which we ſhall ſuppoſe, for example, when full, holds 170 *Scots* gallons of water. The copper is filled three fourths full of water, which is brought to boil: juſt when it begins, the following proportion of aſhes is put into it, *viz.* 30 lb. of blue, and as much white pearl aſhes; 200 lb. of *Marcoſt* aſhes, (or, if they have not theſe, about 300 lb. of *Caſhub)*, 300 lb. of *Muſcovy* or blanch aſhes; the three laſt ought to be well pounded. This liquor is allowed to boil for a quarter of an hour, ſtirring the aſhes from the bottom very often; after which the fire is taken away. The liquor muſt ſtand till it has ſettled, which takes at leaſt ſix hours, and then it is fit for uſe.

Out of their firſt or mother lye, the ſecond, or that uſed in bucking, is made in this manner. Into another copper, holding for example 40 *Scots* gallons, are put 38 gallons of water, 2 lb. ſoft ſoap, and 2 gallons of mother lye; or, for cheapneſs, in place of the ſoap, when they have lye which has been uſed to white linen, called *white-linen lye*, they take 14 gallons of it, leaving out an equal quantity of water. This is called *bucking-lye*.

After the linens are taken up from the field dry, they are ſet in the vat or cave, as their large veſſel is called, in rows, endways, that they may be equally wet by the lye; which, made blood-warm, is now thrown on them, and the cloth is afterwards ſqueezed down by a man with wooden ſhoes. Each row undergoes the ſame operation, until the veſſel is full, or all the cloth in it. At firſt the lye is put on milk-warm, and after ſtanding a little time on the cloth, it is again let off by a cock into the bucking-copper, heated to a greater degree, and then put on the cloth again. This courſe is repeated for ſix or ſeven hours, and the degree of heat gradually increaſed, till it is at the laſt turn or two thrown on boiling hot. The cloth remains after this for three or four hours in the lye; after which the

the lye is let off, thrown away, or uſed in the firſt buckings, and the cloth goes on to another operation.

The cloth is then carried out, generally early in the morning, ſpread on the graſs, pinned, corded down, expoſed to the ſun and air, and watered for the firſt ſix hours, ſo often, that it never is allowed to dry. Afterwards it is allowed to lie till dry ſpots appear before it is watered. After ſeven at night it gets no more water, unleſs it be a very drying night. Next day in the morning and forenoon it is watered twice, or thrice if the day is very dry; but if the weather be not drying, it gets no water: after which it is taken up dry if the green is clean; if not, it is rinſed, mill-waſhed, and laid out to dry again, to become fit for bucking.

This alternate courſe of bucking and watering, is performed for the moſt part from ten to ſixteen times, or more, before the linen is fit for ſouring; gradually increaſing the ſtrength of the lye from the firſt to the middle bucking, and from that gradually decreaſing it till the ſouring begins. The lyes in the middle buckings are generally about a third ſtronger than the firſt and laſt.

Souring, or the application of acids to cloth, is the fourth operation. It is difficult to ſay when this operation ſhould commence, and depends moſtly on a length of experience. When the cloth has an equal colour, and is moſtly freed from the ſprat, or outer bark of the lint, it is then thought fit for ſouring; which is performed in the following manner. Into a large vat or veſſel is poured ſuch a quantity of butter-milk, or ſour milk, as will ſufficiently wet the firſt row of cloth; which is tied up in looſe folds, and preſſed down by two or three men bare-footed. If the milk is thick, about an eighth of water is added to it; if thin, no water. Sours made with bran, or rye meal, and water, are often uſed inſtead of milk, and uſed milk-warm. Over the firſt row of cloth a quantity of milk and water is thrown, to be imbibed by the ſecond; and ſo it is continued till the linen to be ſour-

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ed is ſufficiently wet, and the liquor riſes over the whole. The cloth is then kept down by covers filled with holes, and ſecured with a poſt fixed to the joiſt, that it may not riſe. Some hours after the cloth has been in the ſour, air-bubbles ariſe, a white ſcum is found on the ſurface, and an inteſtine motion goes on in the liquor. In warm weather it appears ſooner, is ſtronger, and ends ſooner, than in cold weather. Juſt before this fermentation, which laſts five or ſix days, is finiſhed, at which time the ſcum falls down, the cloth ſhould be taken out, rinſed, mill-waſhed, and delivered to the women to be waſhed with ſoap and water.

WASHING with ſoap and water, is the fifth operation; and is performed thus. Two women are placed oppoſite at each tub, which is made of very thick ſtaves, ſo that the edges, which ſlope inwards, are about four inches in thickneſs. A ſmall veſſel full of warm water is placed in each tub. The cloth is folded ſo that the ſelvage may be firſt rubbed with ſoap and warm water

length-

length-ways, till it is ſufficiently impregnated with it. In this manner all the parcel is rubbed with ſoap, and afterwards carried to be bucked.

The lye now uſed has no ſoap in it, except what it gets from the cloth; and is equal in ſtrength to the ſtrongeſt formerly uſed, or rather ſtronger, becauſe the cloth is now put in wet. From the former operation theſe lyes are gradually made ſtronger, till the cloth ſeems of an uniform white, nor any darkneſs or brown colour appears in its ground. After this the lye is more ſpeedily weakened than it was increaſed; ſo that the laſt which the cloth gets, is weaker than any it got before.

But the management of ſours is different; for they are uſed ſtrongeſt at firſt, and decreaſed ſo in ſtrength, that the laſt ſour, conſidering the cloth is then always taken up wet, may be reckoned to contain three fourths of water.

From the bucking it goes to the watering,

ing, as formerly, obſerving only to overlap the ſelvages, and tye it down with cords, that it may not tear; then it returns to the four, milling, waſhing, bucking, and watering again. Theſe operations ſucceed one another alternately till the cloth is whitened; at which time it is blued, ſtarched, and dried.

THIS is the method uſed in the whitening our fine cloths. The following is the method uſed in the whitening of the coarſe.

HAVING ſorted the cloths according to their quality, they are ſteeped in the ſame manner as the fine, rinſed, waſhed in the mill, and dried before boiling.

IN this proceſs, boiling ſupplies the place of bucking, as it takes leſs time, and conſequently is thought cheapeſt. It is done in the following manner: 200 lb. *Caſhub* aſhes, 100 lb. white *Muſcovy*, and 30 lb. pearl aſhes, boiled in 105 *Scots* gallons of water for a quarter of an hour, as in the proceſs for the fine cloth, makes the mother or firſt

lye.

lye. The cloth-boiler is then to be filled two thirds full with water and mother lye, about nine parts of the former to one of the latter; ſo that the lye uſed for boiling the coarſe cloth, is about a third weaker than that uſed in bucking the fine. Such a quantity of cloth is put into the foregoing quantity of lye, when cold, as can be well covered by it. The lye is brought gradually to the boil, and kept boiling for two hours; the cloth being fixed down all the time, that it does not riſe above the liquor. The cloth is then taken out, ſpread on the field, and watered, as mentioned before in the fine cloth.

As the ſalts of the lye are not exhauſted by this boiling, the ſame is continued to be uſed all that day, adding, at each boiling, ſo much of the mother lye as will bring it to the ſame ſtrength as at firſt. The lye by boiling loſes in quantity ſomewhat betwixt a third and a fourth; and they reckon that in ſtrength it loſes about a half, becauſe they find in practice, that adding to it half its former ſtrength in freſh lye, has the ſame

effect

effect on cloth. Therefore ſome freſh lye, containing a fourth part of the water, and the half of the ſtrength of the firſt lye, makes the ſecond boiler, as they imagine, equal in ſtrength to the firſt. To the third boiler they add ſomewhat more than the former proportion, and go on ſtill increaſing gradually to the fourth and fifth, which is as much as can be done in a day. The boiler is then cleaned, and next day they begin with freſh lye. Theſe additions of freſh lye ought always to be made by the maſter bleacher, as it requires judgment to bring ſucceeding lyes to the ſame ſtrength as the firſt.

When the cloth comes to get the ſecond boiling, the lye ſhould be a little ſtronger, about a thirtieth part, and the deficiencies made up in the ſame proportion. For ſix or ſeven boilings, or fewer, if the cloth be thin, the lye is increaſed in this way, and then gradually diminiſhed till the cloth is fit for ſouring. The whiteſt cloth ought always to be boiled firſt, that it may not be hurt by what goes before.

In this proceſs, if the cloth cannot be got dry for boiling, buſineſs does not ſtop as in the fine; for after the coarſe has dreeped on racks made for the purpoſe, it is boiled, making the lye ſtrong in proportion to the water in the cloth.

The common method of ſouring coarſe linen, is, to mix ſome warm water and bran in the vat; then put a layer of cloth; then more bran, water, and cloth; and ſo on, till the cave is full. The whole is tramped with mens feet, and fixed as in the former proceſs. 1000 yards of cloth, yard-broad, require betwixt 4 and 6 pecks of bran. The cloth generally lies about three nights and two days in the ſour. Others prepare their ſour twenty-four hours before, by mixing the bran with warm water in a ſeparate veſſel; and before pouring it on the cloth, they dilute it with a ſufficient quantity of water. After the cloth is taken from the ſour, it ought to be well waſhed and rinſed again. It is then given to men to be well ſoaped on a table, and afterwards rubbed betwixt the rubbing-boards. When it comes

comes from them, it ſhould be well milled, and warm water poured on it all the time, if conveniency will allow of it. Two or three of theſe rubbings are ſufficient, and the cloth very ſeldom requires more.

The lye, after the ſouring begins, is decreaſed in ſtrength by degrees, and three boilings after that are commonly ſufficient to finiſh the cloth. Afterwards it is ſtarched, blued, dried, and bittled in a machine made for that purpoſe, which ſupplies the place of a calendar, and is preferred by many to it.

This method uſed in the bleaching of our coarſe cloths, is very like that practiſed in *Ireland* for both fine and coarſe. The only material difference is, that there the bleachers uſe no other aſhes but the kelp or *Caſhub*. A lye is drawn from the former by cold water, which diſſolves the ſalts, and not the ſulphureous particles of the kelp aſhes. This lye is uſed till the cloth is half whitened, and then they lay aſide the kelp lye for one made of *Caſhub* aſhes. I am told that their moſt ſkilful bleachers have laid aſide the uſe of the kelp aſhes.

Thus I have given a ſhort ſketch of the modern, and moſt approved practice of bleaching; a ſketch ſufficient to conduct thoſe who know a little, though not deſigned to inſtruct thoſe who are entirely ignorant. The practice is, no doubt, capable of great improvements. Some are afterwards attempted; others will be diſcovered by time. It is our buſineſs to forward thoſe diſcoveries, and to open the ſpeedieſt way for attaining and divulging them.

PART II.

SECT. I.

Steeping.

IN the preceding hiſtory of bleaching, we may obſerve, that it naturally divides itſelf into ſeveral different branches or parts, all tending to give linen the degree of whiteneſs required. How they effectuate that, comes next under our conſideration. If we can ſettle this queſtion, we ſhall be able to diſcover where the preſent practice ſucceeds, and where it fails; we ſhall be able to ſettle principles, by which the art may receive further improvement; we ſhall reduce it to a regular ſcience.

The general proceſs of bleaching divides itſelf into theſe different parts. 1. Steeping and milling. 2. Bucking and boiling. 3. Alternate watering and drying. 4. Souring. 5. Rubbing with ſoap and warm water, ſtarching, and bluing. We ſhall

ſhall treat of theſe different parts in their order.

Green linen, in the different changes which it has undergone before it arrives at that ſtate, contracts a great foulneſs. This is chiefly communicated to it by the dreſſing compoſed of tallow and ſowen, which is a kind of flummery made of bran, flour, or oat-meal ſeeds. The firſt thing to be done in the bleachfield, is to take off all that filth which is foreign to the flax, would blunt the future action of the ſalts, and might, in unſkilful hands, be fixed in the cloth. This is the deſign of ſteeping.

To accompliſh this end, the cloth is laid to ſteep, or macerate, as chymiſts call it, in blood-warm water. A ſmaller degree of heat would not diſſolve the dreſſing ſo ſoon; and a greater might coagulate and fix, as will afterwards appear, in the body of the linen, thoſe particles which we deſign to carry off. In a few hours the dreſſing made uſe of in weaving is diſſolved, mixed with the water; and as it had acquired ſome degree of acidity, before application, it becomes a ſpecies of ferment. Each ferment promotes its own particular ſpecies of fermentation, or inteſtine motion; the putrid ferment ſets in motion the putrefactive fermentation; the vinous ferment gives riſe to the vinous fermentation; and the acid ferment to the acetous fermentation. That there is a real fermentation going on in ſteeping, one muſt be ſoon convinced, who attends to the air-bubbles which immediately begin to ariſe, to the ſcum which gathers on the ſurface, and to the inteſtine motion, and ſwelling of the whole liquor. That it muſt be the acetous fermentation, appears from this, that the vegetable particles already in part ſoured, muſt firſt undergo this proceſs.

The effect of all fermentations is to ſet the liquor in motion; to raiſe in it a degree of heat; and to emit air-bubbles, which, by carrying up ſome of the light oleaginous particles along with them, produce a ſcum. But as the dreſſing is in ſmall quantity in proportion to the water, theſe effects are gentle and ſlow. The acid ſalts are no

ſooner

ſooner ſeparated, by the acetous fermentation, from the abſorbent earth, which made them not perceptible to the tongue in their former ſtate, than they are united to the oily particles of the tallow, which likewiſe adhere ſuperficially, diſſolve them, and render them, in ſome degree, miſſible with water. In this ſtate they are ſoon waſhed off by the inteſtine motion of the liquor. The conſequence of this operation is, that the cloth comes out freed in a great meaſure from its ſuperficial dirt; and more pliant and ſoft than what it was.

Whenever this inteſtine motion is pretty much abated, and before the ſcum ſubſides, bleachers take out their cloth. The ſcum, when no more air-bubbles riſe to ſupport it, ſeparates, and falls down; and would again communicate to the cloth great part of the filth, when the deſign of this operation was to carry it off. But a longer ſtay would be attended with a much greater diſadvantage. The putrid follows cloſe upon the acetous fermentation: when the latter ends, the former begins. Were this to take

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place in any conſiderable degree, it would render the cloth black and tender, as we ſhall have occaſion afterwards to ſhow. Bleachers cannot be too careful in this article.

The firſt queſtion that ariſes to be determined on theſe principles, is, What is the propereſt liquor for ſteeping cloth? Thoſe uſed by bleachers are plain water; white-linen lye and water, equal parts; and rye meal or bran mixed with water. They always make uſe of lye when they have it; a proof that they think it the beſt. They ſay it ferments moſt. Were that really true, I would think the reaſon ſufficient. But there may be a deception in the caſe. That lye is impregnated with much foulneſs, which by riſing to the ſurface may make a thicker ſcum, produce more air-bubbles, and give the appearance of a ſtronger fermentation. The alkaline ſalts, which make part of its compoſition, will attract the acid ſalts generated by the fermentation, and put a ſtop to their junction with the oils. In this view it may do harm. On the other hand, if the alkaline ſalts in it are not compleatly ſaturated, they may be of uſe in uniting with, and carrying off the greaſy particles of the tallow.

Such oppoſite and unſatisfactory views are the common reſult of theory, when we rely entirely upon it for a deciſion. But ſhall we reſt this important queſtion on no better footing than this? Can we find no certain criterion to judge of the propereſt liquor for ſteeping linen? The deſign of the operation will afford us one. The end propoſed by it is to looſen and carry off the ſuperficial foulneſs of the cloth. That liquor then which carries off moſt of it, and makes the cloth lighteſt, muſt be the propereſt. Let us, by this teſt, try theſe different liquors.

Exp. 1. *June* 25. A web was cut thro' the middle into two pieces; one half of the piece, weighing 4 lb. 1 oz. was ſteeped in milk-warm water; the other half, weighing half an ounce more, was ſteeped in old lye and water, equal parts, and of an equal degree of heat with the former.

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There was some little fermentation in the former, but none in the latter. They were taken out on the 26th, at eleven of the clock in the forenoon, and dried. Each of the pieces now weighed 3 lb. 9½ oz.: so that the old lye, by this experiment, appears better for cleaning cloth than plain water, as the former takes out about an eighth part more than the latter.

That I might compare the effects of bran with those of old lye,

Exp. 2. I cut a web into two pieces, and put one part, weighing 5 lb. 1 oz. into bran and warm water; the other, weighing 5 lb. was put into a mixture of old lye and warm water, a third of the former to two thirds of the latter. They lay forty-eight hours in these liquors; during which time there was little or no fermentation in the old lye, but a considerable degree in the bran and water. When dried, the former piece weighed 4 lb. 13½ oz. the latter 4 lb. 11 oz. That in the bran and water had lost but 3½ oz. but that in the old lye had lost 5 oz.

 That

That I might make the ſame trial on greater quantities of cloth,

Exp. 3. I took ſix pieces of cloth, nearly of the ſame fineneſs, and containing twenty-five yards each. Two of theſe, weighing 20 lb. 1 oz. were ſteeped in old lye; other two, weighing 18 lb. 15 oz. in bran and water; the remaining two, weighing 19 lb. 13 oz. in plain water. All theſe liquors were of an equal degree of warmth. Theſe lay for forty-eight hours, in the month of *June*; during which time the fermentation was ſtrongeſt in the bran and water, next in the plain water, and weakeſt in the lye. Taken out and dried, the firſt weighed 18 lb. 12½ oz. and ſo had loſt 1 lb. 4½ oz.; the ſecond weighed 17 lb. 11 oz. and ſo had loſt 1 lb. 4 oz.; the laſt weighed 17 lb. 12 oz. and ſo had loſt 1 lb. 7 oz. The bran and water, in this laſt experiment, appears to have had a better effect than the old lye; and the plain water than either. This queſtion, therefore, ſtill remains undecided. The only method, however, is pointed out, and a multiplicity of experiments must be tried, before we can determine what liquor is in general best.

After steeping, the cloth is carried to the putstock-mill, to be freed of all its loose foulness. There can be nothing contrived so effectual to answer the purpose as this mill. Its motion is easy, regular, and safe. While it presses gently, it turns the cloth; which is continually washed with a stream of water. Care must be taken that no water be detained in the folds of the linen, otherwise that part may be damaged.

SECT. II.

Bucking and boiling.

This is the most important operation of the whole process, and deserves a thorough examination. Its design is to loosen, and carry off, by the help of alkaline lixives or lyes, that particular substance in cloth, which is the cause of its brown colour.

colour. The ſalts, or aſhes, as the bleachers call them, uſed in the compoſition of the lye, demand, for many reaſons, a particular ſcrutiny; and therefore I ſhall examine them afterwards by themſelves.

THESE aſhes, the pearl excepted, ought to be well pounded, before they are put into the copper; for the *Marcoſt* and *Caſhub* are very hard, and with ſome difficulty yield their ſalts. As theſe two laſt contain a very conſiderable proportion of a real ſulphureous matter, which muſt in ſome degree tinge white cloth; and as this is diſſolved much more by boiling, than by the inferior degrees of heat, while the ſalts may be as well extracted by the latter, I would propoſe that the water ſhould never be brought to boil, and ſhould be continued for ſome time longer under that degree of heat. The pearl aſhes ſhould never be put in till near the end, as they are eaſily diſſolved in water.

IF the ſalts were always of an equal ſtrength, the ſame quantities would make

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a lye equally ſtrong: but they are not. Salts of the ſame name differ very much from one another. The *Muſcovy* aſhes are turning weaker every day, as every bleacher muſt have obſerved, till at laſt they turn quite effete. A decoction from them, when new, muſt differ very much from one when they have been long kept. Hence a neceſſity of ſome exact criterion to diſcover when lyes are of an equal ſtrength. The taſte cannot ſerve, as that is ſo variable, cannot be deſcribed to another, and is blunted by repeated trials. The proof-ball will ſerve the purpoſe of the bleach-field ſufficiently; and, by diſcovering the ſpecific gravity, will ſhow the quantity of alkaline ſalts diſſolved. But it cannot ſhow the dangerous qualities of theſe ſalts; for the leſs cauſtic and leſs heavy this liquor is, the more dangerous and corroſive it may be for the cloth.

This muſt appear a paradox at preſent, but will afterwards be proved by many experiments. The third lye, which they draw from theſe materials by an infuſion

of

of cold water, where I could plainly taſte the lime, appears to me more dangerous than the firſt. The ſecond lye, which they extract from the ſame aſhes, and which is reckoned about a third in ſtrength, when compared to the firſt, muſt be of the ſame nature; nor do I think it ſhould be uſed without an addition of pearl aſhes, which will correct it.

It is taken for a general rule, That the ſolution of any body in its menſtruum is equally diffuſed through the whole liquor. The bleachers depending on this, uſe equal quantities of the top and bottom of their lye, when once clear and ſettled; taking it for granted, that there is an equal quantity of ſalts in equal quantities of the lye. But if there is not, the miſtake may be of fatal conſequence; as the lye may be in ſome places ſtronger than what the cloth can with ſafety bear. That general law of ſolution muſt have taken its riſe from particular experiments, and not from reaſoning. Whether a ſufficient number of experiments have been tried to aſcertain this point,

point, and to eſtabliſh an undoubted general rule, may be called in queſtion.

But when I had diſcovered that lime makes part of the diſſolved ſubſtance, and reflected how long its groſſer parts will continue ſuſpended in water, there appeared ſtronger reaſons for my ſuſpecting that this rule, though it may be pretty general, does not take place here; at leaſt it is worth the purſuit of experiment.

Exp. 4. I weighed at the bleachfield a piece of glaſs in ſome cold lye, after it had been boiled, ſtood for two days, and about the fourth part of it had been uſed. The glaſs weighed 3 drachms 1½ grains in the lye, and 3 drachms 7½ grains in river-water. The ſame glaſs weighed in the ſame lye, when almoſt all uſed, 2 grains leſs than it had done before. This ſhows, that the laſt of the lye contained a third more of the diſſolved body; and, conſequently, was a third ſtronger than the firſt of the lye.

As this might, perhaps, be owing to a

continuation of the ſolution of the ſalts, I repeated the experiment in a different way.

Exp. 5. I took from the ſurface ſome of the lye, after the ſalts were diſſolved, and the liquor was become clear. At the ſame time I immerſed a bottle, fixed to a long ſtick, ſo near the bottom, as not to raiſe the aſhes there, and, by pulling out the cork by a ſtring, filled the bottle full of the lye near the bottom. The glaſs weighed in river-water 3 drachms $38\frac{1}{2}$ grains; in the lye taken from the ſurface 3 drachms $34\frac{1}{2}$ grains; and in the lye taken from the bottom 3 drachms $31\frac{1}{2}$ grains. This experiment ſhows, that the lye at the bottom was, in this caſe, $\frac{3}{4}$ ſtronger than the lye at the ſurface.

At other times when I tried the ſame experiment, I found no difference in the ſpecific gravity; and, therefore, I leave it as a queſtion yet doubtful, though deſerving to be aſcertained by thoſe who have an opportunity of doing it. As the lye ſtands continually on the aſhes, there can

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be no doubt but what is used last must be stronger than the first. I would, therefore, recommend, to general practice, the method used by Mr *John Christie*, who draws off the lye, after it has settled, into a second receptacle, and leaves the ashes behind. By this means it never can turn stronger; and he has it in his power to mix the top and bottom, which cannot be done so long as it stands on the ashes.

Having considered the lye, let us next inquire how it acts. On this inquiry depends almost the whole theory of bleaching, as its action on cloth is, at least in this country, absolutely necessary. We shall see, in some experiments which follow on the natural effects of these ashes, that one effect they have on cloth, is the diminishing of its weight; and that their whitening power is, generally, in proportion to their weakening power. Hence arises a probability, that these lyes act by removing somewhat from the cloth, and that the loss of this substance is the cause of whiteness. This appears yet plainer, when the bucking, which lafts from *Saturday* night to *Monday* morning, is attended to. There I have feen evident figns of a folution going on from the quantity of air-bubbles arifing, when the liquor was almoft cold.

There are various and different opinions with regard to the operation of thefe falts: That they act by altering the external texture of the cloth, or by feparating the mucilaginous parts from the reft, or by extracting the oil which is laid up in the cells of the plant. The laft is the general opinion, or rather conjecture, for none of them deferves any better name; but we may venture to affirm, that it is fo without any better title to pre-eminence, than what the others have. Alkaline falts diffolve oils, therefore thefe falts diffolve the cellular oil of the cloth, is all the foundation which this theory has to reft on; too flight, when unfupported by experiment, to be relied on.

In fettling this queftion, we fhall not only fix the theory of bleaching, but likewife wiſe that of the lithontriptic quality of medicines, whoſe effects on the human calculus are obſerved to be the ſame as the effects of theſe materials on cloth. The ſolvents of the ſtone, and the bleaching materials, are the ſame. They produce ſimilar effects on both; ſuch as diminution of weight, a white colour, the generation of much elaſtic air, and at laſt a diſſolution or ſeparation of parts. But their method of acting has not yet been aſcertained by any certain and concluſive experiment. Let us then bring the queſtion, if we can, to that teſt.

WAX is whitened by being expoſed to the influence of the ſun, air, and moiſture. A diſcovery of the changes made on it by bleaching, may throw a light upon the queſtion.

Exp. 6. Six drachms of wax were ſliced down, expoſed on a ſouth window, *September* 10. and watered. That day being clear and warm, bleached the wax more than all the following. It ſeemed to me to whiten

whiten quicker when it had no water thrown on it, than when it had. *Sept*. 15. it was very white, and 1 drachm 3 grains lighter. $3\frac{1}{2}$ drachms of this bleached wax, and as much of unbleached, taken from the ſame piece, were made into two candles of the ſame length and thickneſs, having cotton wicks of the ſame kind. The bleached candle burned one hour thirty-three minutes; the unbleached three minutes longer. The former run down four times, the latter never. The former had an obſcure light and dull flame; the latter had a clear pleaſant one, of a blue colour at the bottom. The former when burning ſeemed to have its wick thicker, and its flame nearer the wax, than the latter. The former was brittle, the latter not. It plainly appears from theſe facts, that the unbleached wax was more inflammable than the bleached; and that the latter had loſt ſo much of an inflammable ſubſtance, as it had loſt in weight; and conſequently the ſubſtance loſt in bleaching of wax is the oily part. Dr *Haſes* obſerves, that wax in diſtillation affords an inflammable vapour.

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As I had not an opportunity of repeating the former experiment, I do not look on it as entirely conclusive; for it is possible that some of the dust, flying about in the air, might have mixed with the bleached wax, and so have rendered it less inflammable. Nor do I think the analogical reasoning from wax to linen without objections. Let us try then if we cannot procure the substance extracted from the cloth, show it to the eye, and examine its different properties. The proper place to find it, is in a lye already used, and fully impregnated with these colouring particles.

Exp. 7. I got in the bleachfield some lye, which had been used all that day for boiling coarse linen, which was tolerably white, and had been twice boiled before. There could be no dressing remaining in these webs. No soap had ever touched that parcel; nor do they mix soap with the lye used for coarse cloth. Some of this impregnated lye was evaporated, and left a dark-coloured matter behind. This substance felt oily betwixt the fingers, but would

would not lather in water as ſoap does. It deflagrated with nitre in fuſion, and afforded a tincture to ſpirit of wine. By this experiment the ſalts ſeem to have an oily inflammable ſubſtance joined with them.

COULD we ſeparate this colouring ſubſtance from theſe ſalts, and exhibit it by itſelf, ſo that it might become the object of experiment, the queſtion would be ſoon decided. Here chymiſtry lends us its aſſiſtance. Whatever has a ſtronger affinity or attraction to the ſalts with which it is joined, than this ſubſtance has, muſt ſet it at liberty, and make it viſible. Acids attract alkaline ſalt from all other bodies; and therefore will ſerve our purpoſe.

Exp. 8. Into a quantity of the impregnated lye mentioned in the former experiment, I poured in oil of vitriol. Some bubbles of air aroſe, an inteſtine motion was to be perceived, and the liquor changed its colour from a dark to a turbid white. It curdled like a ſolution of ſoap, and a ſcum ſoon gathered on the ſurface, about half an inch

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in thickneſs, the deepneſs of the liquor not being above ſix inches. What was below was now pretty clear. A great deal of the ſame matter lay in the bottom; and I obſerved, that the ſubſtance on the ſurface was precipitated, and ſhowed itſelf heavier than water, when the particles of air, attached to it in great plenty, were diſpelled by heat. This ſubſtance was in colour darker than the cloth which had been boiled in it.

I procured a conſiderable quantity of it by ſkimming it off. When I tried to mix it with water, it always fell to the bottom. When dried by the air, it diminiſhed very much in its ſize, and turned as black as a coal. In this ſtate it deflagrated ſtrongly with nitre in fuſion; gave a ſtrong tincture to ſpirit of wine; and when put on a red-hot iron, burnt very ſlowly, as if it contained a heavy ponderous oil; and left ſome earth behind.

From the inflammability of this ſubſtance, its rejecting of water, and diſſolving in ſpirit of wine, we diſcover its oleaginous nature;

ture; but from its great ſpecific gravity we ſee, that it differs very much from the expreſſed or cellular oil of vegetables; and yet more from their mucilage. That it diſſolves in ſpirit of wine, is not a certain argument of its differing from expreſſed oils; becauſe theſe, when joined to alkaline ſalts, and recovered again by acids, become ſoluble in ſpirit of wine. The quantity of earthy powder left behind after burning, ſhows that it contains many of the ſolid particles of the flax. The ſubſtance extracted from cloth by alkaline lyes appears then to be a compoſition of a heavy oil, and the ſolid earthy particles of the flax. Whether this heavy oil differs originally in the plant, from the oil expreſſed from its cells, or whether the latter is converted into the former, by loſing in ſolution great part of its air, I cannot determine; nor is it neceſſary. At preſent they ſeem widely different.

In what manner theſe ſalts act ſo as to diſſolve the oils, and detach the ſolid particles, whether from a certain polarity, as Dr

Dr *Hales* imagines, or from other cauſes, of which the imagination can ſuggeſt many, is not allowed us certainly to know. The ſpeculation is too ſubtile to admit of experiments, and too uncertain to be truſted to without theſe. It is enough for us to know on what principles in the cloth theſe ſalts operate. We ſee evidently how much cloth muſt be weakened by an improper uſe of theſe ſalts, as we find the ſolid particles themſelves are ſeparated.

It is neceſſary that cloth ſhould be dry before bucking, that the ſalts may enter into the body of the cloth along with the water; for they will not enter in ſuch quantity, if it be wet; and by acting too powerfully on the external threads, may endanger them.

The degree of heat is a very material circumſtance in this operation. As the action of the ſalts is always in proportion to the heat, it would appear more proper to begin with a boiling heat, by which a great deal of time and labour might be ſaved.

The reaſon why this method is not follow-ed, appears to be this. If any vegetable or vegetable ſubſtance is to be ſoftened, and to have its juices extracted, it is found more proper to give it gentle degrees of heat at firſt, and to advance gradually, than to plunge it all at once in boiling water. This laſt degree of heat is ſo ſtrong, that when applied at once to a vegetable, it hardens, inſtead of ſoftening its texture. Dried vegetables are immediately put into boiling water by cooks, that theſe ſubſtances may preſerve their green colour, which is only to be done by hindering them from turning too ſoft. Boiling water has the ſame effect on animal ſubſtances; for if ſalt beef is put into it, the water is kept from getting at the ſalts, from the outſide of the beef being hardened.

But when we conſider, how much of an oily ſubſtance there is in the cloth, eſpecially at firſt, which will for ſome time keep off the water, and how the twiſting of the threads, and cloſeneſs of the texture, hinders the water from penetrating, we

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ſhall find, that if boiling water were put on it at once, the cloth might be liable, in ſeveral parts, to a dry heat, which would be much worſe than a wet one. That the lyes have not acceſs to all parts of the cloth, at firſt, appears plainly from this, That when it has lain, after the firſt bucking, till all the lyes are waſhed out, it is as black, in ſome parts, as when it was ſteeped. This muſt be owing to the diſcharge of the colouring particles from thoſe places to which the lye has acceſs, and to their remaining where it has not. It would ſeem adviſeable, then, in the firſt bucking or two, when the cloth is foul, to uſe the lye conſiderably below the boiling point; that by this ſoaking, or maceration, the foulneſs may be entirely diſcharged, and the cloth quite opened for the ſpeedy reception of the boiling lye in the buckings which follow.

The lyes ſhould likewiſe be weakeſt in the firſt buckings, becauſe then they act only on the more external parts; whereas, when the cloth is more opened, and the field

field of action is increaſed, the active powers ought to be ſo too. For this reaſon they are at the ſtrongeſt after ſome ſourings.

I was of opinion, that the cloth was allowed to lie too ſhort time in the lye, and that more time on this account was conſumed in the bleaching of cloth than was neceſſary. What confirmed my ſuſpicions, was, that I obſerved the cloth, which lay in the bucking-vat from *Saturday* night to *Monday* morning, come out of a deeper colour, and when expoſed to the air, became whiter, than the others of the ſame parcel, which had been in the lye for twelve hours only. I cauſed the experiment to be tried on a whole parcel every time they were bucked; and they advanced faſter, and with as great ſafety, as other pieces which were managed in the common way. As to the effect of ſoap mixed with the lye, I ſhall have occaſion afterwards to ſhow, that it has no power in correcting the dangerous qualities of the

lye.

lye. At the ſame time we ſhall diſcover, what is the proper corrector.

THE only thing that now remains to be conſidered, is, the management of the coarſe cloth, where boiling is ſubſtituted in place of bucking. This ſpecies of linen cannot afford the time and labour neceſſary for the latter operation; and therefore they muſt undergo a ſhorter, and more active method. As the heat continues longer at the degree of boiling, the lyes uſed to the coarſe cloth muſt be weaker than thoſe uſed to the fine. There is not ſo much danger from heat in the coarſe, as in the fine cloth, becauſe the former is of a more open texture, and will allow the lye to penetrate more ſpeedily. In the cloſer kinds, however, I would adviſe, that the firſt application of the ſalts ſhould be made without a boiling heat.

I cannot help greatly condemning the method generally uſed, of boiling all the cloth of that day in the ſame lye. I can ſee no certainty of having all the lyes of the ſame

ſame ſtrength, becauſe neither the taſte nor proof-ball can be of uſe here; the taſte, becauſe the oily matter ſheathes the ſalts; the proof-ball, becauſe there is another ſubſtance here beſides ſalts. But I am ſure of this, that ſo much filth, as a former experiment ſhowed in lye often uſed, cannot but communicate ſome of itſelf to the cloth, and inſtead of advancing, retard its whiteneſs. It will appear afterwards, from experiments, that cloth boiled in a foul lye becomes heavier, and conſequently takes in part of its foulneſs. If it is done for cheapneſs, I am not of opinion, that it will turn out ſo on a further examination; for the laſt additions of freſh lye muſt be blunted greatly by the foulneſs in the old lye; and the bleachers themſelves obſerve, that they have not ſuch a ſtrong effect as the firſt. No lye, therefore, can with any advantage be uſed above twice.

SECT. III.

Alternate watering and drying.

AFTER the cloth has been bucked, it is carried out to the field, and frequently watered for the firſt ſix hours. For if, during that time, when it is ſtrongly impregnated with ſalts, it is allowed to dry, the ſalts approaching cloſer together, and, aſſiſted by a greater degree of heat, increaſing always in proportion to the drineſs of the cloth, act with greater force, and deſtroy its very texture. After this time, dry ſpots are allowed to appear before it gets any water. In this ſtate I imagine it profits moſt, as the latter part of the evaporation comes from the more internal parts of the cloth, and will carry away moſt from thoſe parts. The bleaching of the wax, in a preceding experiment, helps to convince me of this; for it ſeemed to whiten moſt when the laſt particles of water were going off.

THIS continual evaporation from the ſurface of the cloth ſhows, that the deſign of the operation is to carry off ſomewhat remaining after the former proceſs of bucking. This appears likewiſe from a fact known to all bleachers, that the upper ſide of cloth, where the evaporation is ſtrongeſt, attains to a greater degree of whiteneſs than the under ſide. But it is placed beyond all doubt by the experiment in ſect. 1. of part 4.; where it appears, that cloth turns much lighter by being expoſed to the influence of the ſun, air, and winds, even though the ſalts have been waſhed out of it.

WHAT, then, is this ſubſtance? As we have diſcovered in the former ſection, that the whitening, in the operation of bucking, depends on the extracting or looſening the heavy oil, and ſolid particles of the flax; it appears highly probable, that the effects of watering, and expoſition to the ſun, air, and winds, are produced by the evaporation of the ſame ſubſtance, joined to the ſalts, with which compoſite body the cloth

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is impregnated when expofed on the field. That thefe falts are in a great meafure carried off or deftroyed, appears from the cloth's being allowed to dry without any danger, after the evaporation has gone on for fome time. If we can fhow, that oils and falts, when joined together, are capable of being exhaled, in this manner, by the heat of the atmofphere, we fhall reduce this queftion to a very great degree of certainty.

Exp. 9. *Sept.* 10. I expofed, in a fouth-weft window, half an oz. of *Caftile* foap, fliced down, and watered. *Sept.* 14. when well dried, it weighed but 3 dr. 6 gr. *Sept.* 22. it weighed 2 dr. 2 gr. *Sept.* 24. it weighed 1 dr. 50 gr. It then feemed a very little whiter; but was much more mucilaginous in its tafte, and had no degree of faltnefs, which it had before.

It appears, from this experiment, that foap is fo volatile, when watered, and expofed to air not very warm, that it lofes above the half of its weight in fourteen days.

The ſame muſt happen to the ſaponaceous ſubſtance, formed from the conjunction of the alkaline ſalts, heavy oil, and earthy particles of the flax. The whole deſign, then, of this operation, which, by way of pre-eminence, gets the name of *bleaching*, is to carry off, by the evaporation of water, whatever has been looſened by the former proceſs of bucking.

Against this doctrine there may be brought two objections, ſeemingly of great weight. It is a general opinion amongſt bleachers, that linen whitens quicker in *March* and *April*, than in any other months: but as the evaporation cannot be ſo great at that time, as when the ſun has a greater heat; hence the whitening of cloth is not in proportion to the degree of evaporation; and therefore the former cannot be owing to the latter. This objection vaniſhes, when we conſider, that the cloth which comes firſt into the bleachfield, in the ſpring, is cloſely attended, having no other to interfere with it, for ſome time; and, as it is the whiteſt, gets, in the after buck-

ings,

ings, the firſt of the lye; while the ſecond parcel is often bucked with what has been uſed to the firſt. Were the fact true, on which the objection is founded, this would be a ſufficient anſwer to the objection. But it appears not to be true, from an obſervation of Mr *John Chryſtie*, That cloth laid down in the beginning of *June*, and finiſhed in *September*, takes generally leſs work, and undergoes fewer operations, than what is laid down in *March*, and finiſhed in *June*.

The other objection is, That cloth dries much faſter in windy weather than in calm ſunſhine; but it does not bleach ſo faſt. This would ſeem to ſhow, that the ſun has ſome particular influence independent on evaporation. In anſwer to this objection, let it be conſidered, that it is not the evaporation from the ſurface, but from the more internal parts, as I ſaid before, that is of benefit to the cloth. Now, this latter evaporation muſt be much ſtronger in ſunſhine than in windy weather, on account of the heat of the ſun, which will make the

the cloth more open; while the coldneſs of windy weather muſt ſhut it up, ſo that the evaporation will all be from the ſurface. Clear ſunſhine, with a very little wind, is obſerved to be the beſt weather for bleaching; a convincing proof that this reaſoning is juſt.

It would ſeem to follow as a corollary from this reaſoning, that the number of waterings ſhould, in general, be in proportion to the ſtrength of the lye; for the ſtronger the lye is, the more there is to be evaporated; and the greater the danger, in caſe the cloth ſhould be allowed to dry. But there is an exception to this general rule, ariſing from the conſideration of another circumſtance. It is obſerved, that cloth, when brown, dries ſooner, than when it becomes whiter, ariſing from the cloſeneſs and oilineſs, which it then has, not allowing the water a free paſſage. Perhaps that colour may retain a greater degree of heat, and in that way aſſiſt a very little. Cloth, therefore, after the firſt buckings,

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muſt be more carefully watered than after the laſt.

It follows likewiſe from this reaſoning, that the ſoil of the bleachfield ſhould be gravelly or ſandy, that the water may paſs quickly through it, and that the heat may be increaſed by the reflection of the ſoil: for the ſucceſs of this operation depends on the mutual action of heat and evaporation. It is likewiſe neceſſary that the water ſhould be light, ſoft, and free from mud or dirt, which, not being able to riſe along with the water, muſt remain behind. When there is much of this, it becomes neceſſary to rinſe the cloth in water, and then give it a milling, to take out the dirt; elſe it would be fixed in the cloth by the following bucking, as it is not ſoluble by the lye.

This operation has more attributed to it by bleachers than it can juſtly claim. The cloth appears, even to the eye, to whiten under theſe alternate waterings and dryings; and theſe, naturally, get the honour of it, when it more properly belongs to the

former

former operation. Here lies the fallacy. Alkaline ſalts give a very high colour to the decoctions, or infuſions of vegetables. This is probably owing to the ſolution of the oleaginous colouring particles of the plant; which particles, being opened and ſeparated by the ſalts, occupy a greater ſpace, and give a deep colour to the liquor. The cloth participates of the liquor and colour. Hence bleachers always judge of the goodneſs of the bucking by the deepneſs of its colour. The rule, in general, is good. I obſerve, that in thoſe buckings which continue from the *Saturday* night to the *Monday* morning, the cloth has always the deepeſt colour. When that cloth has been expoſed ſome hours to the influence of the air, theſe colouring particles, which are but looſely attached to it, are evaporated, and the linen appears of a brighter colour. This operation does no more than complete what the former had almoſt finiſhed. If its own merit were thoroughly known, there would be no occaſion to attribute that of another operation to it. Thread, and open cloths, ſuch as diaper, may be reduced to a great degree of whitenefs, after one bucking, by it alone. No cloth, as would appear, can attain to a bright whitenefs without it.

Since the only advantage of watering is the removal of the falts, and what they have diffolved, might we not effectuate this by fome cheaper, and more certain method? For it occupies many hands; and muft depend, altogether, on the uncertainty of the weather; fo that, in the beginning of the feafon, the bleacher is often obliged to repeat his buckings without bleaching. We might take out the alkaline falts by acids; but then the other fubftance would be left alone in the cloth, nor would any wafhing be able to remove it. Mill-wafhing appears a more probable method of taking out both falts and oils; and it would feem that this might, in a great meafure, fupply the place of watering; but upon trial it does not fucceed. Two parcels of linen were managed equally in every other refpect, except in this, That one was watered, and expofed to the influence of the air, and the other was only mill-washed. This method was followed until they were fit for souring. The cloth which had been mill-washed, had a remarkable green colour, and did not recover the bright colour of the pieces managed in the common way, until it had been treated like them for a fortnight. The green colour was certainly owing to a precipitation of the sulphureous particles, with which the lye is impregnated, upon the surface of the cloth; owing to the salts being washed off more speedily than the sulphur, to which they are united in the lye. The attachment betwixt these two bodies, we know, is very loose, and the separation easily made. Evaporation, then, alone is sufficient to carry off these sulphureous particles.

SECT. IV.

Souring.

IT is well known to all chymists, and will afterwards appear, that alkaline salts are convertible, by different methods, into absorbent earths. Frequent solution in water,

water, and evaporation of it again, is one of theſe. This tranſmutation, then, of theſe ſalts, which are not volatiliſed, or waſhed away, muſt be continually going on in the cloth under theſe alternate waterings and dryings of the former proceſs. Not much, indeed, after the firſt two or three buckings; becauſe the ſalts, not having entered deep into the cloth, are eaſily waſhed off, or evaporated. But when they penetrate into the very compoſition of the laſt and minuteſt fibres, of which the firſt veſſels are made, they find greater difficulty of eſcaping again, and muſt be more ſubject to this tranſmutation. But if we conſider the bleaching aſhes as a compoſition of lime and alkaline ſalts, we muſt diſcover a freſh fund for the depoſition of this abſorbent earth. The common cauſtic, a compoſition of this very kind, ſoon converts itſelf, if expoſed to the open air, into a harmleſs earthy powder.

Frequent buckings and bleachings load the cloth with this ſubſtance. It becomes, then, neceſſary to take it out. No waſhing can do that, becauſe earth is not ſoluble in water. Nothing but acids can remove it. Theſe are attracted by the abſorbent earth, join themſelves to it, and compoſe a kind of neutral imperfect ſalt, which is ſoluble in water; and therefore eaſily waſhed out of the cloth. The acid liquors commonly uſed are butter milk, which is reckoned the beſt; ſour milk; infuſions of bran, rye-meal, *&c.* kept for ſome days till they ſour. Sour whey is thought to give the cloth a yellow colour.

The linen ought to be dried before it is put in the ſour, that the acid particles may penetrate, along with the watery, thro' the whole. A few hours after it has been there, air-bubbles ariſe, the liquor ſwells, and a thick ſcum is formed; manifeſt ſigns of a fermentation. The following experiment ſhows the degree of heat which attends it.

Exp. 10. *May* 25. I put a thermometer of *Fahrenheit*'s into ſome butter milk of which the bleachers were compoſing their ſours, and

and which ſtood in a vat adjoining to another, where the milk was the ſame, and the ſouring proceſs had been going on for two days. After the thermometer had been twenty minutes in the butter milk, the mercury ſtood at 64 degrees. In the ſouring vat it roſe to 68 degrees. An increaſe of 4 degrees ſhows a pretty briſk inteſtine motion.

To what are all theſe effects owing? To the acetous fermentation going on in thoſe vegetable liquors, whoſe acids, extricating themſelves, produce heat, inteſtine motion, and air-bubbles. As the change is ſlow, the proceſs takes five or ſix days before it is finiſhed. During this time the acid particles are continually uniting themſelves to the abſorbent earth in the cloth. That this fermentation goes on in the liquor alone, appears from this conſideration, that the ſame effects, *viz.* air-bubbles, and ſcum, are to be ſeen in the butter milk alone. The only effect, then, it has, ſo far as I can ſee, is, by the ſmall degree of heat, and inteſtine motion, which attend

it,

it, to aſſiſt the junction of the acid and abſorbent particles. We ſhall preſently ſee, that this proceſs may be carried on, to as great advantage, without any fermentation; and therefore it appears not abſolutely neceſſary.

When theſe abſorbent particles are fully ſaturated, the remaining acids may unite with, and have ſome ſmall effect in extracting the colouring particles. This appears from the two following experiments.

Exp. 11. *Sept.* 20. A piece of cloth which had been ſteeped, weighing 41½ gr. was put into a half-pound of butter milk, whigged, and well ſoured, by a mixture of water, and by boiling. *Sept.* 24. when taken out, and waſhed in water, it appeared a very little whiter. The mineral acids, as will appear afterwards, whiten cloth, even though they are very much diluted.

Just before the acetous fermentation is finiſhed, the cloth ſhould be taken out; otherwiſe the ſcum will fall down, and lodge in in the cloth, and the putrefaction, which then begins, will weaken it. This appears from the following experiment.

Exp. 12. *Sept.* 16. A piece of cloth weighing 42 gr. was laid in butter milk unwhigged. *Nov.* 15. the milk had a putrified ſmell. The cloth was a little whiter, but very tender; and weighed, when well waſhed in warm water, and dried, 40 gr.

All the ſours made of bran, rye-meal, &c. ought to be prepared before uſe; for by this means ſo much time will be ſaved. Beſides, when the water is poured upon the cloth, and bran, as is done in the management of coarſe cloth, the linen is not in a better ſituation than if it had been taken up wet from the field; and by this means the acid particles cannot penetrate ſo deep. Again, this method of mixing the bran with the cloth, may be attended with yet worſe conſequences. All vegetable ſubſtances, when much preſſed, fall into the putreſcent, and not the acetous fermentation. This muſt, and does happen to the bran preſſed

betwixt

betwixt the different layers of the linen. I had occaſion to ſee it one day, in a bleach-field, when they were drawing a parcel of coarſe cloth ſoured in this manner. The bran had attained to a conſiderable degree of putrefaction, but the liquor had not. The cloth, immediately above and below this putrid bran, muſt have been weakened by it. For theſe obvious reaſons I would propoſe, that all the ſours ſhould be prepared before the cloth is ſteeped in them; and that none of the bran, or meal, ſhould be mixed with the cloth.

The ſours are uſed ſtrongeſt at firſt, and gradually weakened till the cloth has attained to its whiteneſs. In the firſt ſourings, there is more of the earthy matter in the cloth, from the many buckings it has undergone, than what there can be afterwards. As the quantity of this matter decreaſes, ſo ſhould the ſtrength of the ſour. I am not, however, of opinion, that there is the leaſt danger at any time, from too ſtrong a ſour. Why they ſhould not be uſed ſomewhat ſooner than they are, I could never ſee any reaſon.

WHAT is moſt wanted in this operation, is, a more expeditious and cheaper method of obtaining the ſame end. As it takes five or ſix days, it retards the whitening of the cloth conſiderably; and as bleachers are obliged to ſend for milk to a great diſtance, it becomes very dear. This laſt conſideration makes them keep it ſo long, that, when uſed, it can have no good effect; perhaps it may have a bad.

THERE is one conſideration that may lead us to ſhorten the time. It is obſerved, that the ſouring proceſs is ſooner finiſhed in warm than in cold weather. Heat quickens the fermentation, by aiding the inteſtine motion. I would propoſe, then, that the vats ſhould not be buried in the ground, as they always are, which muſt keep them cold; and that there ſhould be pipes along the walls of the room, to give it that degree of heat, which, on trial, may be found to anſwer beſt. I am of opinion, that there

 are

are few days in ſummer ſo hot as is neceſſary; and that the beginning and end of the ſeaſon, is by very much too cold. That this is no ideal ſcheme, the following fact is a ſufficient proof. There are two vats in *Salton* bleachfield, adjoining to a partition-wall, at the back of which there is a kitchen-fire. In theſe vats the ſouring proceſs is finiſhed in three days, whereas it laſts five or ſix days in the others placed round the ſame room.

THIS improvement, though it ſhortens the time of ſouring a very little, yet is no remedy againſt the ſcarcity and dearneſs of milk ſours. Such a liquor as would ſerve our purpoſe, muſt be found either among the vegetable acids, which have no further fermentation to undergo, or among the mineral acids. The former are a large claſs, and contain within themſelves many different ſpecies, ſuch as the acid juice of ſeveral plants, vinegars made of fermented liquors, and acid ſalts called *tartars*. But there is one objection againſt all theſe vegetable acids: They all contain, along with the acid,

a

a great quantity of oleaginous particles, which would not fail to difcolour the cloth. Befides, the demand of the bleachfields would raife their price too high.

The mineral acids have neither of thefe objections. They are exceedingly cheap, and contain no oil, though many chymifts have afferted that they did. I will freely own, that, at firft, I had no great opinion of their fuccefs; from two reafons; their want of all fermentation, which I then looked on as neceffary; and their extreme corrofivenefs. But the experience of two different fummers, in two different bleachfields, has convinced me, that they will anfwer all the purpofes of the milk and bran fours; nay, in feveral refpects, be much preferable to them. I have feen many pieces of fine cloth, which had no other fours, but thofe of vitriol, and were as white and ftrong as thofe bleached in the common way. I have cut feveral webs through the middle, and bleached one half with milk, and the other with vitriol, gave both the ſame number of operations, and the latter were as white and ſtrong as the former.

The method, in which it has been hitherto uſed, is this. The proportion of the oil of vitriol to the water, with which it is diluted, is half an ounce, or at moſt three quarters of the former, to a gallon of the latter. As the milk ſours are diminiſhed in ſtrength, ſo ought the vitriol ſours. The whole quantity of the oil of vitriol to be uſed, may be firſt mixed with a ſmall quantity of water, then added to the whole quantity of water, and well mixed together. The water ſhould be milk-warm; by which means the acid particles will penetrate further, and operate ſooner. The cloth ſhould then be put dry into the liquor.

It is obſerved, that this ſour performs its taſk much ſooner than thoſe of milk or bran; ſo that Mr *John Chryſtie*, in making the trial, uſed to lay the milk ſours twenty-four hours before the vitriol. I am of opinion, that five hours will do as much with this ſour, as five days with the common

ſort,

ſort. But the cloth can receive no harm in allowing it to remain for ſome days in the ſour, but rather, on the contrary, an advantage, as we ſhall have occaſion afterwards to obſerve. The cloth is then taken out, well rinſed, and mill-waſhed in the ordinary way.

The liquor, while the cloth lies in this ſour, is leſs acid the ſecond day than the firſt, leſs the third than the ſecond, and ſo diminiſhes by degrees. At firſt it is clear, but by degrees a mucilaginous ſubſtance is obſerved to float in it, when put into a glaſs. This foulneſs increaſes every day. This ſubſtance extracted by the acid, is the ſame with what is extracted by the alkaline ſalts; and blunts the acidity of the former, as I have ſhown it does the alkaleſcency of the latter. This will appear more plain, when I come to ſhow the natural effects of theſe acid ſalts on unbleached cloth. Hence the liquor loſes, by degrees, its acidity. But as the acid ſalts do not unite ſo equally with oleaginous ſubſtances, as the alkaline do, the liquor is not ſo uniformly tinged in the

the former, as in the latter caſe, and the mucous ſubſtance preſents itſelf floating in it.

It is obſerved, that, in the firſt ſouring, which is the ſtrongeſt, the liquor, which was a pretty ſtrong acid before the cloth was put in, immediately afterwards becomes quite vapid; a proof how very ſoon it performs its taſk. But in the following operations, as the linen advances in whiteneſs, the acidity continues much longer; ſo that in the laſt operations the liquor loſes very little of its acidity. This happens although the firſt buckings, after the firſt ſourings, are increaſed in ſtrength, while the ſours are diminiſhed. There are two cauſes to which this is owing. The texture of the cloth is now ſo opened, that although the lyes are ſtrong, the alkaline ſalts and abſorbent earth are eaſily waſhed out; and the oleaginous particles are, in a great meaſure, removed, which help to blunt the acidity of the liquor.

I have heard two objections brought againſt the uſe of vitriol ſours. One is, That the proceſs of ſouring with milk is performed by a fermentation; and as there is no fermentation in the vitriol ſours, they cannot ſerve our purpoſe ſo well: the other, That they may hurt the texture of the cloth. The anſwer to the former objection is very ſhort, That the vitriol ſours operate ſucceſsfully without a fermentation, as experience ſhows; and therefore in them a fermentation is not neceſſary. The ſame objection might be made to ſtrike againſt the vegetable ſours, That as the mineral acids operate without fermentation, therefore the vegetable, which ferment, will not ſucceed; but the truth is, that both ſucceed. The vegetable liquors muſt ferment, that their acids may be ſet free; but the mineral acids neither ſtand in need, nor are capable of any ſuch change. This ſhows evidently, that all the advantage of fermentation is to diſengage the acid ſalts, that they may exert themſelves on the cloth.

As to the latter objection, That oil of vitriol,

triol, being a very corroſive body, may hurt the cloth; that will vaniſh likewiſe, when it is conſidered how much the vitriol is diluted with water, that the liquor is not ſtronger than vinegar, and that it may be ſafely taken into the human body. But there will remain no doubt of its ſafety, when I come afterwards to ſhow, that I have kept linen in a ſtrong ſour of vitriol for many months, and that the cloth was as ſtrong after it was taken out, as when it was put in. Theſe experiments convinced me of its ſafety, before I had experience of its uſe in the bleachfield.

That it may be uſed with ſafety, much ſtronger than what is neceſſary in the bleachfield, appears from the following experiment with regard to the ſtamping of linen. After the linen is boiled in a lye of aſhes, it is bleached for ſome time. After this, in order to make it receive the colour, it is ſteeped in a ſour of water and oil of vitriol, about fifteen times ſtronger than that made uſe of in the bleachfield; for to 100 gallons of water are added two and a half

half of oil of vitriol. Into this quantity of liquor, made ſo warm as the hand can juſt be held in it, is put ſeven pieces of 28 yards each. The linen remains in it about two hours, and comes out remarkably whiter. The fine cloth often undergoes this operation twice. Nor is there any danger if the oil of vitriol is well mixed with the water. But if the two are not well mixed together, and the oil of vitriol remains, in ſome parts, undiluted, the cloth is corroded into holes.

Let us now take a view of the advantages which the vitriol ſours muſt have over the milk. The latter is full of oleaginous particles, ſome of which muſt be left in the cloth: but the caſe is worſe if the ſcum is allowed to precipitate upon the cloth. The former is liable to neither of theſe objections.

The common ſours haſten very faſt to corruption; and if, from want of proper care, they ever arrive at that ſtate, muſt damage the cloth very much. As the milk is kept very long, it is often corrupted before it is uſed; and, without acting as a four, has all the bad effects of putrefaction. The vitriol ſours are not ſubject to putrefaction.

The milk takes five days to perform its taſk; but the vitriol ſours do it in as many hours; nay, perhaps, in as many minutes. Their junction with the abſorbent particles in the cloth muſt be immediate, whenever theſe acid particles enter with the water. An unanſwerable proof that the fact is ſo, ariſes from the circumſtances which happen when the cloth is firſt ſteeped in the vitriol ſour; the cloth has no ſooner imbibed the acid liquor than it loſes all acidity, and becomes immediately vapid. This effect of vitriol ſours muſt be of great advantage in the bleachfield, as the bleachers are at preſent hindered from enjoying the ſeaſon by the tedioufneſs of the ſouring proceſs. The whole round of operations requires ſeven days; to anſwer which they muſt have ſeven parcels, which are often mixing together, and cauſing miſtakes. As three

days,

days, at moſt, will be ſufficient for all the operations when vitriol ſours are uſed, there will be no more than three parcels. The cloth will be kept a ſhorter time in the bleachfield, and ſo arrive ſooner at market.

The milk ſours are very dear, and often difficult to be got; but the vitriol are cheap, may be eaſily procured, and at any time.

There is yet another advantage in the uſe of vitriol, and that is its power of whitening cloth. It will appear, afterwards, by experiments, that, even in this diluted ſtate, its whitening power is very conſiderable. We have already ſeen, that it removes the ſame colouring particles, which the alkaline lyes do. What of it then remains, after the alkaline and abſorbent particles are neutralized in the cloth, muſt act on theſe colouring particles, and help to whiten the cloth. That this is really the caſe, appears from the following fact. Mr *Chryſtie* being obliged to chuſe twenty of the whiteſt pieces out of a hundred, five of the twenty were taken out of ſeven pieces which were bleached with vitriol.

From both experience and reaſon, I muſt then give it as my opinion, That it would be for the advantage of our linen manufacture, to uſe vitriol in place of milk ſours.

SECT. V.

Hand-rubbing with ſoap and warm water, rubbing-boards, ſtarching, and bluing.

After the cloth comes from the ſouring, it ſhould be well waſhed in the waſhing-mill, to take off all the acid particles which adhere to its ſurface. All acids diſcompoſe ſoap, by ſeparating the alkaline ſalts and oily parts from one another. Were this to happen on the ſurface of the cloth, the oil would remain; nor would the waſhing-mill afterwards be able to carry it off.

From

From the washing-mill the fine cloth is carried to be rubbed by womens hands, with soap and water. As the liquors which are generally employed for souring, are impregnated with oily particles, many of these must lodge in the cloth, and remain, notwithstanding the preceding milling. It is probable, that all the heavy oils are not evaporated by bleaching. Hence it becomes necessary to apply soap and warm water, which unite with, dissolve, and carry them off. It is observed, that if the cloth, when it is pretty white, gets too much soap, the following bleaching is apt to make it yellow: on that account they often wring out the soap. I believe it would be proper to give it always a milling with warm water, before bucking, to take out the soap and loosened dirt more effectually. The preceding fact is a strong argument in its favour.

It is a matter worth inquiring into, whether hard or soft soap is best for cloth. Most bleachers, I think, agree, that hard soap is apt to leave a yellowness in the

cloth,

cloth. I havê been told, that the uſe of hard ſoap is diſcharged in *Holland*. As there muſt be a conſiderable quantity of ſea-ſalt in this kind, which is not in the ſoft, and as this ſalt appears prejudicial to cloth, I would prefer the latter.

THE management of the coarſe cloth is very different, in this operation, from the fine. Inſtead of being rubbed with hands, which would be too expenſive, it is laid on a table, run over with ſoap, and then put betwixt the rubbing-boards, which have ridges and grooves from one ſide to another, like teeth. Theſe boards have ſmall ledges to keep in the ſoap and water, which ſaves the cloth. They are moved by hands, or a water-wheel, which is more equal, and cheaper. The cloth is drawn, by degrees, through the boards, by men who attend; or, which is more equal, and cheaper, the ſame water-wheel moves two rollers, with ridge and groove, ſo that the former enters the latter; and, by a gentle motion round their own axis, pull the cloth gradually through the boards.

THIS

THIS mill was invented in *Ireland* about thirty years ago. The *Irish* bleachers use it for their fine, as well as coarse cloth. However necessary it may be for the latter, on account of its low price, I see no reason, on that account, for using it to the former. These rubbing-boards were discharged, some years ago, in *Ireland*, by the Trustees for the manufactures of that country, convinced from long experience of their bad effects. But as proper care was not taken to instruct the bleachers, by degrees, in a safer method, they continued in the old, made a party, and kept possession of the rubbing-boards. There were considerable improvements made in them in this country; such as the addition of the ledges, to keep the cloth moist; and of the rollers, which pull the cloth more gradually than mens hands. These improvements were first made in *Salton* bleachfield.

THE objections against these rubbing-boards, I think, are unanswerable. By rubbing on such an unequal surface, the solid fibrous part of the cloth is wore; by which

means

means the cloth is much thinned, and, in a great meaſure, weakened, before it comes to the market. As a proof of what I ſay, if the water which comes from the cloth in the rubbing-boards, is examined, it will be found full of cottony fibrous matter. Theſe boards give the cloth a cottony ſurface, ſo that it does not keep long clean. Again, they flatten the threads, and take away all that roundneſs and firmneſs, which is the diſtinguiſhing property of cloth bleached in the *Dutch* method.

For theſe reaſons I am of opinion, that they are entirely prejudicial to fine cloth; and hope they will not be employed in this country to it, as I know they ſtill are by many bleachers who follow the *Iriſh* method. As they ſeem to be, in ſome meaſure, neceſſary to render the expence of bleaching coarſe linen leſs, they ought never to be uſed above twice, or thrice at moſt. They might, I think, be rendered much more ſafe, by lining their inſides with ſome ſoft elaſtic ſubſtance, that will not wear the cloth ſo much as the wooden teeth do. I am told Mr *Chryſtie* at *Perth* has lined his boards with ſhort hair, for ſome years, and finds that it anſwers very well.

AFTER the coarſe linen has undergone a rubbing, it ſhould be immediately milled for an hour, and warm water poured now and then on it to make it lather. This milling has very good effects; for it cleans the cloth of all the dirt and filth which the rubbing-boards have looſened, and which, at the next boiling, would diſcolour the cloth. Beſides, it is obſerved, that it makes the cloth leſs cottony, and more firm, than when whitened by rubbing alone.

THE laſt operation is that of ſtarching and bluing. It often happened, that the cloth, when expoſed to the weather to be dried after this operation, got rain; which undid all again, and forced the bleacher to a new expence. To remedy this inconvenience, Mr *John Chryſtie*, ſome years ago, invented the dry-houſe, where the cloth may be dried, after this operation, in any weather. This invention meets with univerſal approbation.

PART III.

SECT. I.

Blue pearl aſhes.

THE ſalts or aſhes are the principal agents uſed by the bleacher; and therefore merit our conſideration. A phyſician who underſtood not the compoſition of the medicines he uſed, would be reckoned ignorant: and why not the bleacher who uſes inſtruments unknown to him? His ignorance, however, is not blameable. The utmoſt ſkill in his art cannot teach him to analyſe theſe aſhes into their conſtituent parts. For that knowledge he muſt depend on chymiſtry, which, operating in the gentle method of ſolution and evaporation, preſents to us the natural conſtituent parts of bodies. The force of ſtrong chymical fire muſt alter theſe. A heat as gentle as the ſummer ſun, cannot.

THIS analyſis, by diſcovering to us the conſtituent

conſtituent parts of theſe ſalts, will teach us the true way of compounding and manufacturing them at home, of procuring them perhaps at a cheaper rate, and not depending on foreign countries for what is abſolutely neceſſary in carrying on our home manufactures. It will be attended with another advantage. As the bleaching aſhes of the ſame name differ very much in ſtrength from one another, this analyſis will teach the bleacher how to examine them; how to diſcover the quantity of ſalts in them; and, conſequently, to aſcertain their value and uſe. It will ſhow him how to diſcover the qualities of a new ſalt.

Let us imitate the mathematicians in their method of inveſtigating truth. Let us ſet out entirely ignorant of the nature, properties, or compoſition of theſe different ſalts; and, by the help of ſome data, or uncontroverted concluſions from eſtabliſhed experiments, proceed to their examination.

The blue pearl aſhes are of a light bluiſh

iſh colour; have a hot and pungent taſte; and diſſolve in the mouth.

Exp. 13. In order to diſcover what effect acids would have on theſe aſhes, and what quantity of the former the latter would deſtroy; from which I might be able to form ſome judgment of the quantity and ſtrength of the ſalt they contained; I took a drachm of blue pearl aſhes, and poured on it a mixture of one part ſpirit of nitre, and ſix parts water; which I ſhall always afterwards uſe, and call the *acid mixture*. An effervеſcence aroſe, and, before it was finiſhed, 12 teaſpoonfuls of the mixture were required. This effervеſcence with each ſpoonful of the acid mixture was violent, but did not laſt long. A reddiſh powder was precipitated to the bottom. When ſaturated, it had a nitrous taſte.

It is proper here to give a caution. This experiment does not afford a certain concluſion, either as to the proportion or ſtrength of the real alkaline ſalts which theſe aſhes contain; as there are other bodies beſides alkaline

alkaline ſalts, that effervefce with acids, ſuch as abſorbent and calcarious earths, and quick-lime. No certain concluſion can be drawn, unleſs we were certain, that none of theſe bodies were mixed with the aſhes; which we cannot be, until we have performed the proper trials, fit for diſcovering the preſence of theſe different bodies.

Exp. 14. To ſeparate the pure ſaline from the earthy part of theſe aſhes, a half-pound of blue pearl was mixed with three *Engliſh* pints of water, and put over the fire. The ſalt was diſſolved when the water was milk-warm. The ſolution tried ſeveral ways, gave me no ſigns of containing any ſulphur. It was ſtrained through brown paper, and left in it a reſiduum, that weighed, when dried, 3 gr. By another experiment I got a much greater quantity of earthy ſubſtance. The ſtrained ſolution was afterwards boiled into 3 gills, and ſet in a cellar, that I might diſcover if there was any nitre, ſea ſalt, or any other kind of ſalt mixed with the aſhes. Theſe ſalts will diſcover themſelves by their cryſtalliſation.

After

After the liquor had ſtood a fortnight, there appeared at the bottom of the cup, ſome cryſtals that ſeemed to be much akin to the tartarus vitriolatus. Some of the alkaline ſalts, and a white powder like the reſiduum, had mixed with theſe cryſtals. This neutral ſalt will likewiſe fall to the bottom of the cup, when the ſolution is near evaporated. The liquor being evaporated, gave me $5\frac{1}{2}$ oz. of ſalt.

THIS ſalt was much of the colour of the white pearl aſhes; it had loſt all its former pellucidity, and was brown on the top, and white beneath. The taſte was much the ſame as before. When half an hour from the fire, it began to turn moiſt.

Exp. 15. To try the ſtrength of theſe ſalts, I diſſolved half a drachm in a ſpoonful of water, and added the acid mixture to it. During the efferveſcence a whitiſh powder fell to the bottom. Four tea-ſpoonfuls of the acid completed the ſaturation. The liquor being evaporated, gave a nitre.

BY

By this experiment it appears, that the ſalts extracted by boiling from the aſhes, are not ſo ſtrongly alkaline, as the aſhes themſelves; and that the boiling, by ſeparating their component parts, which appears by their loſs of weight, and precipitation of a powder, weakens them. This ought to teach bleachers not to boil thoſe ſalts, that are eaſily diſſolved in water without boiling, for by that means they weaken them conſiderably, but to add them to the lye when cooling.

The reſiduum which remained in the brown paper being dried over the fire, taſted and looked like chalk, had no ſaline pungency, nor was diſſolvable in the mouth.

Exp. 16. To three quarters of this I added the acid mixture; a ſtrong efferveſcence enſued, and a half tea-ſpoonful was conſumed before it ceaſed.

It appears from this experiment, that this earth has as ſtrong a power of deſtroying acids, as the ſalts themſelves. Is this earth,

earth, then, the only abſorbent or alkaline part in the compoſition of alkaline ſalts? Has their other conſtituent part or parts, rendered volatile, or changed, by boiling, no oppoſition to acids? So it would ſeem. I ſhall conſider this earthy part more fully in the next ſection.

THE concluſion, then, that we draw from the foregoing experiments, is, That the blue pearl aſhes are a very pure alkaline ſalt, with a ſmall proportion of vitriolated tartar, and abſorbent earth.

SECT. II.

White pearl aſhes.

THEY are of a white colour, diſſolvable in the mouth, hot, and pungent.

Exp. 17. To a drachm of the white pearl aſhes, I added the acid mixture. An effervescence aroſe, which laſted till the

ſalts

ſalts had deſtroyed ten tea-ſpoonfuls. When ſaturated, it had a nitrous taſte, and a white powder at the bottom. Theſe aſhes, then, are a fifth part leſs antacid than the laſt.

Exp. 18. To diſcover the proportion of their earthy part to their ſaline, half a pound was put into three *Engliſh* pints of water; which diſſolved when the water began to turn warm; but not juſt ſo ſoon as the blue pearl aſhes. The ſolution gave no ſign of containing ſulphur. When ſtrained, I got 50 grains of reſiduum. It was afterwards boiled into three gills, and ſtood fourteen days in a cellar. I diſcovered ſome tartarus vitriolatus, and a good deal of a white powder, like the reſiduum which had fallen to the bottom. The ſolution evaporated, gave me of pure ſalt 5 oz. and 7 dr.

THIS ſalt was brown above, and white beneath; and, as I thought, had ſcarce ſo pungent a taſte as before boiling. It began to diſſolve in the air, when it had been half an hour from the fire.

Exp. 19. Half a drachm was diſſolved in a ſpoonful of water. They ſeemed more difficult to be diſſolved than the ſalts of the blue pearl. The ſolution took four tea-ſpoonfuls of the acid mixture to ſaturate it, and let fall a copious white powder, as the ſalts of the blue pearl had done.

The reſiduum is darker-coloured, than that of the blue pearl; but has much the ſame chalky taſte.

Exp. 20. I put ſix grains of it in a glaſs, and poured two tea-ſpoonfuls of water on it. A half tea-ſpoonful of the acid mixture raiſed a ſtrong efferveſcence, and ſaturated it.

Exp. 21. I put into a reverberatory furnace ſome of the reſiduum. After it had been there two hours, it had not the taſte of lime, nor afforded me a lime-water. Alkaline ſalts, each time that they are boiled, and ſtrained, leave a ſimilar earth behind them; and, if the operation be continued, the whole may be converted into this

this earth. If ſalts are kept long in fuſion, they are turned, at laſt, into the ſame earth *. I got ſome of this earthy matter from pearl aſhes, which were ſtrained through brown paper before they were boiled, but could not reduce that earth to quick-lime by the force of a reverberatory furnace. This earth, then, is the fixed baſis of alkaline ſalts; and appears, by theſe experiments, to be of an abſorbent, and not a calcarious nature, as all the chymiſts, ſo far as I know, have univerſally called it. Let us now try to diſcover the other volatile principle, or principles, that were joined to this earthy baſe in the compoſition of alkaline ſalts.

There are two different opinions with regard to the formation or origin of theſe alkaline ſalts. The former is, That they pre-exiſt in vegetables in the ſame form, and are ſeparated from the other parts, by incineration †. This opinion is

* Junker de ſalib. alkal. fix. p. 372.

† Burning to white aſhes.

now univerſally exploded, as no ſuch ſalt has ever, without the aſſiſtance of fire, been diſcovered in plants, though it is found elſewhere. The other opinion is, That they are produced, by the act of combuſtion, from ſome new combination of the parts of the plant, that were not combined before. This is the opinion of *Stahl*, *Boerhaave*, *Junker*, and almoſt all the chymiſts. They ſeem not to be agreed, however, as to the principles that go to their compoſition. *Stahl* imagines they ariſe from a junction of the heavy inflammable part with the ſaline. From the known experiments of making alkaline ſalt from nitre and any inflammable body, he draws this concluſion. *Item, itaque hoc in vegetabilium incineratione contingere, et ita alkalia illorum nihil aliud eſſe quam partem illorum nitroſam, cum bituminoſa deflagrando commixtam, ſequentia phænomena confirmant**. *Junker* differs from *Stahl*, in aſſociating the inflammable, acid, and terrene parts toge-

* Art. 3. de ſal. volat. plantar. fund. chym. A book publiſhed by one of his ſcholars; and though not by himſelf, yet with his connivance.

ther;

ther: *Sub ingenti autem illarum commotione, pars acida ex mixtione ſua ibidem reſolvitur, et terrenis partibus illiditur; cum quibus, ſi cum fixiore ſulphurea firmiter complicatur, generat et conſtituit ſubſtantiam illam alkalinam fixam* *. The arguments produced by them in proof of an inflammable principle, do not ſeem, to me, to be ſufficient. The argument that *Stahl* brings in defence of his opinion, is this. If a plant, which affords plenty of alkaline ſalt, be dried, bruiſed, and digeſted in ſpirit of wine, until all the reſinous part be extracted, then burnt in a gentle fire, *(leni igne)*, it will afford a nitrous ſalt, but not an alkaline one; becauſe, ſays *Stahl*, the reſinous part, that ſhould go to its compoſition, is carried off. This concluſion of *Stahl* ſeems to me too ſtrong. It proves that an inflammable principle is neceſſary to the production of an alkaline ſalt, but it proves no more. To ſay that it is neceſſary in the compoſition, is ſaying more than the experiment will allow. The inflam-

* De ſalibus alkalinis fixis, tab. 66.

mable

mable principle is abſolutely neceſſary in the production of alkaline ſalts, in order to make a great commotion and heat in the vegetable, by which alone the acid parts are to be driven off. A gentle external fire, after the oil, which is the ſupport of the internal fire, is withdrawn, can never be ſufficient for this purpoſe. Chymiſts have obſerved, that a ſmothered fire produces little or no alkaline ſalt. This ſhows a flame to be abſolutely neceſſary.

THIS reaſoning ſerves, likewiſe, as an anſwer to the experiment mentioned before, by which an alkaline ſalt is produced from nitre and an inflammable body. *Junker* has another argument in ſupport of an inflammable principle. "If," ſays he, "an alkaline ſalt ſaturated with diſtilled vinegar "is again expoſed to the fire, it gains a "black colour; which is an undoubted "proof, that it contains a heavy inflam-"mable ſubſtance." Undoubted I'll allow it to be; but whence comes it? From the diſtilled vinegar, to be ſure, which contains a heavy oil in conſiderable quantity.

THESE

These experiments, therefore, are not ſufficient to prove the exiſtence of an inflammable principle in alkaline ſalts. But the experiments that prove the contrary, are very ſtrong. Whatever body contains an inflammable principle, deflagrates with nitre in fuſion; but alkaline ſalts do not. Whenever alkaline ſalts and an inflammable body are joined, they emit, when the mineral acids are poured over them, a ſulphureous ſmell; but alkaline ſalts do not. When an oleaginous ſubſtance is joined to alkaline ſalts, a ſubſtance different from either, called *ſoap*, is formed. The chymiſts themſelves acknowledge, that alkaline ſalts may be formed of two bodies, neither of which contain an inflammable oleaginous principle. Theſe quotations from *Stahl*, ſhow how much he differs from himſelf. Fund. chym. part. 2. p. 50. *Calx viva, vel cum vitriolo, vel ſale communi, aut ſpiritu acido, mixta, et calcinata, præbet ſal fixum acerrimum, ſolubile.* p. 52. *Sic ſpiritus acidus ſalis cum creta mixtus, mutatur in ſal alkali fixum.* Ibid. p. 54. *Nempe ſpiritus acidus ſalis commixtus cum creta, coral. uſt. calce viva, tranſ-*

mutatur

mutatur in ſal alkali, quod eoſdem effectus præbet in ſolutionibus et præcipitationibus cum ſale quodam fixo alkalino. Theſe experiments, if he has performed them, ſhow plainly, that an inflammable principle is not neceſſary. But I muſt own, that theſe experiments, though they make againſt the theory I have been endeavouring to refute, did not ſucceed with me, as they have done with *Stahl*.

I ſhall relate what ſucceſs I have had in theſe experiments. In the firſt quotation he orders the neutral body, made of quick-lime and the ſpirit of ſalt, to be calcined; and though he does not mention calcination in the two laſt, it muſt be underſtood; for otherwiſe the bodies ſaturated would be neutral, and not alkaline.

Exp. 22. Two ſcruples of chalk being fully ſaturated with ſpirit of ſea ſalt, gave a yellow, bitter, pungent liquor. This, when dried, and put immediately into a gentle fire for ſome minutes, gave no ſigns of efferveſcing with acids, but attracted the moi-

ſture

ſture ſtrongly. It was again put into a crucible, and ſet in the middle of a kitchen-fire, for two hours. Still it raiſed no effervescence with acids; but had ſome of the other properties of alkaline ſalts, ſuch as turning moiſt in the air, diſſolving in water, and turning ſyrup of violets green. It was afterwards put into a reverberatory furnace for an hour and a half; but by this heat it ſeemed to have been turned into glaſs; for there was nothing to be found in the crucible, and its bottom had a glazed-like appearance. Thus a calcarious earth, invitreſcible before, is turned, by the addition of an acid, into glaſs.

Exp. 23. Two ſcruples of quick-lime were ſaturated with ſpirit of ſea ſalt, which produced a yellow cauſtic liquor, that burnt the tongue when applied to it. Being evaporated, and kept in the kitchen-fire for two hours, I got a ſubſtance that ſcarcely diſſolved in water, nor in the leaſt efferveſced with acids; but turned ſyrup of violets green, and taſted juſt like alkaline ſalts. It was put for an hour and a half in a reverberatory furnace, and I had 22 gr. of a gritty undiſſolvable ſubſtance. Thus the acid has changed the calcarious baſe into an earthy ſubſtance, that is of a different nature from quick-lime.

I purſued theſe trials further, to ſee if I could ſucceed better with the other mineral acids.

Exp. 24. Chalk was ſaturated with ſpirit of nitre, and then put into a kitchen-fire for half an hour. I got a ſubſtance which was undiſſolvable in water, and to me appeared to be like chalk.

Exp. 25. Quick-lime ſaturated with the ſpirit of vitriol, afforded a bitter cauſtic liquor, which excoriated my tongue. When evaporated, it was put into the kitchen-fire for an hour. I got a brown ſubſtance, which was a little hot in the mouth, did not appear to be diſſolvable in water, and afforded a lime-water.

From theſe experiments it appears, that a a ſubſtance formed of an acid ſalt and abſorbent earth, has ſome of the properties of alkaline ſalts, while it wants others. The chymiſts, for they generally follow *Stahl* in this opinion, have been led aſtray by the cauſtic taſte of the production. Notwithſtanding the ill ſucceſs of theſe experiments, to prove, that alkaline ſalts are a compound of an abſorbent earth and an acid, yet I ſtill think there is a great degree of probability in that ſide of the queſtion, from the following reaſons.

Those plants which contain no acid, afford no alkaline fixed ſalt, ſuch as onions, muſtard, &c. If ſuch plants as contain an acid, are diſtilled, and the acid forced over with a ſtrong fire, they afford leſs alkaline ſalt. Alkaline ſalts are made more alkaline by a ſtronger heat than what was uſed before; which ſhows, that more of the acid has been driven off by the fire. " Nitre, " without any addition, kept long in fu" ſion, acquires a cauſtic alkaline nature *." There are ſcarce any of the properties of

* Junker de ſalib. alkal. fix.

alkaline ſalts, but what belong either to the abſorbent earths, or acids. To the former they owe their fixedneſs in the fire, their attraction and effervеſcence with acids, with all the properties that depend on this cauſe, and their power of turning the ſyrup of violets green: to the latter, their cauſtic power, their ſolubility in water, their tranſparency when diſſolved in it, their attraction of moiſture, their junction with oils, and their vitreſcency. If there are any particles of fire added to, and fixed in the alkaline ſalts, as it is probable there may be, theſe may a little vary ſome of the properties: As for inſtance, alkaline ſalts attract acids with a greater force, than abſorbent earths do, though the laſt deſtroy a greater quantity. This ſtronger attraction in alkaline ſalts may be owing to their parts being more opened, than thoſe of the earth, to the junction of ſome particles of fire, or, perhaps, to the remaining acid particles, between whom and the other acid there may be an attraction. This doctrine will receive an additional ſtrength, by conſidering, out of what ſubſtance or ſubſtances, pre-exiſting in in the plant, thoſe alkaline ſalts are formed.

The general opinion of chymiſts, as I mentioned before, is, that they are formed by a new combination of principles during combuſtion. I imagine they are formed by a ſeparation. The eſſential ſalts of plants ſeem to be the product of an acid, and an abſorbent earth; for theſe two, as we have ſhowed before, are ſufficient to make a neutral ſalt. There is no fact, I think, more clearly proved, than that there are acid particles continually circulating, in greater or leſs quantity, with the air. I have tried the aſhes of plants, and I find they contain a great quantity of abſorbent particles. Hence, then, the eſſential ſalts of vegetables. But theſe ſalts extracted, cryſtalliſed, and calcined by themſelves, afford, as *Boerhaave* informs us, an alkaline ſalt. Why not likewiſe when the vegetable is burnt? This is the moſt natural way of accounting for their origin, without flying to new combinations during combuſtion. The fire will evaporate all the water, diſpel the greateſt part of the acid from theſe neu-

tral

tral ſalts; and there will remain a ſmall quantity of pure ſolid acid, joined to an abſorbent earth *, with, perhaps, ſome particles of fire in the compoſition.

SECT. III.

Muſcovy or blanch aſhes.

THE bulk of mankind are led by names. That two ſubſtances enjoy the ſame denomination, is enough, to the

* Long after theſe papers were wrote, I diſcovered the ſame opinion, with regard to the compoſition of alkaline ſalts, in the writings of a celebrated chymiſt, *Homberg des principes de chymie en general.*——*Memoires pour l' annee* 1702.

Ces ſels fixes lixiviels ne ſont autre choſe qu'un reſte des ſels acides, que le feu de la calcination n'a pu ſeparer de la terre du mixte, qui lui ſert de baſe, et qui ſe diſſolvent enſemble dans l'eau commune.

The following quotation from the ſame diſſertation, appears to be an experimental proof of this doctrine. *La ſeconde occaſion ou ces ſels fixes peuvent devenir volatils, eſt de les deſſoudre dans de l'eau, le tenir pendant quelque temps en digeſtion, enſuite de les filtrer et evaporer, puis recommencer ces operations pluſieurs fois, juſque à ce qu' à la fin ces ſels ſe cryſtalliſent: alors il le faut meler avec du bol, et les deſtiller à grand feu, il en viendra une eſprit acide: les ſels fixes retires de la tete-morte traite de la même maniere en rendra encore un peu, mais en trés petite quantité.*

carelefs obferver, to rank them in the fame clafs, and to imagine their compofition and qualities, in general, much alike: elfe how would the *Mufcovy* afhes have ever been claffed with thofe above explained, when the external fenfes, without further help, might, if attended to, have difcovered the fallacy, and fhown thefe to be of a very different nature from the two former?

MUSCOVY afhes have very much the appearance of flaked lime; and are, like it, friable betwixt the fingers. The tongue, when applied, adheres to them. The firft tafte which one perceives, is that of an alkaline falt; but this goes foon away, and leaves a ftrong tafte of lime, which is peculiar to this falt. They never turn moift in the air; which plainly difcovers, that they contain little alkaline falt. Some fmall bits of charcoal are to be feen in their compofition.

Exp. 27. On the addition of the acid mixture to a drachm of *Mufcovy* afhes, there arofe an ebullition, which, though it was not

not violent, yet continued long after the acid was joined to it. When they had got 4 ſpoonfuls, I took out a little piece to break it; and to the taſte it ſeemed inſipid, and gritty like a ſtone. They conſumed 17 tea-ſpoonfuls. When the ſaturation was fully completed, it taſted bitter, and very different from the two former ſalts.

Exp. 28. To ſeparate the ſalts from theſe aſhes, I put half a pound in two pounds of water, and kept it pretty warm over the fire, but did not let it boil, for fear of diſſipating the volatile parts, if there were any, till I thought the ſalts would be diſſolved; then I poured off the water. A half-pint was added to the remaining powder, which, after boiling ſome minutes, was likewiſe poured off. It was treated twice more in the ſame way. The laſt that came off was not ſalt, but had a taſte like lime-water. The decoction all together, when ſtrained, was about three pints. Though carefully examined, it gave no ſign of containing ſulphur. After all was ſtrained, there remained in the paper 5½ dr. of a whitiſh powder,

der, which added to 2 oz. 5 dr. of undiſſolvable ſubſtance, that lay at the bottom of the pot, when the water was poured off, made in all 3 oz. 5½ dr. This decoction boiled into half a pint, and ſet for a fortnight in a cellar, gave no ſign of any other ſalt. When all the water was evaporated, I had 10 dr. 15 gr. of a very cauſtic ſalt, which ſeemed lighter than the ſalts of the blue and pearl aſhes, and turned very moiſt, when kept from the fire twenty-four hours.

It appears that 3 oz. 18. gr. have been rendered volatile by the water, a greater quantity than in any of the two former ſalts. This loſs of ſubſtance probably ariſes from the watery parts contained in theſe aſhes.

Exp. 29. To aſcertain the ſtrength of theſe ſalts, I diſſolved half a drachm in water. The acid mixture produced a ſtronger efferveſcence than with the former ſalts; and four and a half tea-ſpoonfuls of it were required to ſaturate it. A browniſh powder fell to the bottom of the glaſs in great quantity. Theſe ſalts, then, appear to be ſtronger antacids than the former two, by their greater ebullition, and the greater quantity of acid they conſumed. If we are to judge by the laſt article, their proportionate antacid ſtrength (for this experiment may be no rule as to their other qualities) is as nine to eight. It appears likewiſe, that the antacid quality of the aſhes themſelves is almoſt double to that of the ſalts. Can this be owing to the volatility of ſome acid parts? or to the greater antacid power of the other part that is mixed with theſe ſalts? This laſt appears probable from the following experiments, which diſcover a ſtronger antacid power in the reſiduum than in the ſalts.

Let us now examine the reſiduum, which, as I mentioned before, was of two ſorts; what remained in the bottom of the pot, and what remained in the gray paper. The firſt was of a light brown colour, and run together into hard pieces; the latter was white, and a powder.

Exp.

Exp. 30. Thirty grains of the latter effervefced ftrongly with the acid mixture, and confumed five and a half tea-fpoonfuls. Thus, though the refiduum appears ftronger than the falts, yet it feems much weaker in its antacid power than the afhes.

I poured water on a quantity of both refiduums in two different cups, and let it ftand all night. The water had a tafte of chalk and water, next morning, but not of lime-water.

This fubftance might ftill be calcarious, though it had no parts now foluble in water; for the reiterated boiling in water might have carried off thefe foluble parts, as we know it does. My next trial, therefore, was, to fee if I could reduce it to quick-lime again, by the force of the fire. There is no doubt but that the fire will reduce into quick-lime, at a fecond trial, thofe calcarious parts, which had not got a fufficient fire the firft time, and on that account were not calcined into quick-lime. We often fee undiffolved in the water pieces of lime-ſtone, which would have been reduced to quick-lime had they got ſufficient fire. But whether thoſe parts of quick-lime, which have been ſufficiently calcined, and have been robbed of all thoſe particles that are ſoluble in water, can again be reduced to quick-lime, is not, I think, clearly aſcertained by authors who have wrote on this ſubject.

Exp. 31. To determine this queſtion, I tried the following experiment. A conſiderable quantity of quick-lime was quenched in water, ſo that it roſe ſome inches above the lime. The whole was often ſtirred about. After it was completely ſettled, I took of the ſurface of the lime, which was compoſed of thoſe particles that had been the longeſt ſuſpended in water, and of courſe the fineſt. This lime, that could have no particles in it but what had been ſeparated by the water, and therefore none but thoſe that had been changed into quick-lime by the fire, was boiled in water until it no longer taſted like lime-water. This took two days boiling. The

effete

effete lime was then put into a reverberatory furnace, for an hour and a half. This reduced it again to ſtrong quick-lime; for it ſucked up the water very greedily, fell down into powder, and afforded a ſtrong lime-water with a pellicle.

Exp. 32. Some of the reſiduum of the white *Muſcovy* aſhes, put in a ſtrong kitchen-fire for two afternoons, and afterwards mixed with water, did not fall; after it had ſtood ſome time, the water had no pellicle; nor a taſte of lime-water, but as if chalk and water had been mixed together.

But the ſame ſubſtance, kept in a reverberatory furnace for an hour and a half, gave me a ſtrong lime-water with a pellicle. The reſiduum then appears to be the *caput mortuum* of quick-lime.

Exp. 33. Another experiment of the ſame kind I tried at the bleachfield. I took ſome of the *caput mortuum*, which remains in the copper after the lye is taken off, and

will

will not diſſolve in water. It had no taſte but that of an earth. It was calcined in a large ſtrong fire for two hours; when cold, water was poured on it, which made an ebullition, and cauſed it to fall down. When the liquor had ſtood all night, it had the pellicle and taſte, though not very ſtrong, of lime-water.

LET us ſee if we cannot make a lime-water from the *Muſcovy* aſhes, without the aſſiſtance of fire.

Exp. 34. Two ounces of them were waſhed, by continual addition of freſh water, till the water that came off from them had no longer a ſalt taſte. Then I poured ſome water over them, and let the mixture ſtand all night. Next morning it had the pellicle of lime-water; and appeared, on taſting, to be good lime-water.

As a further proof, we could have diſtilled ſome of the aſhes, after the ſalts had been waſhed out, with crude ammoniac ſalt, and ſeen whether the volatile ſpirit was like that

that produced from lime and that ſalt; for a ſpirit produced in this way, is found to differ very much from a ſpirit produced by an alkaline ſalt in place of lime. But my ingenious friend Dr *Cullen* has prevented me; and, having diſtilled *Muſcovy* aſhes and ſal ammoniac together, got ſuch a ſpirit as is procured from the latter and quick-lime. By this experiment he made it highly probable, that lime entered into the compoſition of the *Muſcovy* aſhes; and is, therefore, juſtly intitled to the merit of being the firſt diſcoverer.

From theſe experiments the following corollary follows, That the *Muſcovy* aſhes contain an alkaline ſalt and lime; and the latter in much greater proportion than the former.

SECT. IV.

Caſhub aſhes.

These aſhes are extremely hard, of the colour of iron ſtone, with many ſhining

ſhining particles, and ſome pieces of charcoal in them. They have a ſaline taſte, with a conſiderable degree of pungency. They feel gritty in the mouth, when broke in pieces by the teeth; for they will not diſſolve.

Exp. 35. When the ſaline mixture was poured over them, they did not efferveſce violently, but long; and the liquor had a very black powder on the top and bottom. They emitted a ſulphureous ſmell; and, when the ſaturation was completed, which was done by 13 tea-ſpoonfuls of the acid mixture, they had a ſulphureous taſte.

Exp. 36. To extract the ſalts, a half-pound was boiled in a pint of water; then that water poured off, and a half-pint put on the aſhes again; and ſo on till the water taſted no longer ſalt. This boiling took twenty-four hours. The laſt that came off had a ſtrong taſte of ſulphur, and was blackiſh.

Exp. 37. To try if there was any ſulphur in the decoction, I put a piece of ſilver into to it; which in a few minutes was turned almoſt quite black.

Exp. 38. This experiment corroborates the former. Into 1 oz. of the decoction I poured as much ſpirit of nitre as ſaturated it. During the addition of the ſpirit there was a ſtrong ſmell of a volatile ſulphur. The liquor turned lacteſcent, and let fall to the bottom a light-coloured powder in conſiderable quantity. I ſtrained the whole through brown paper; and there was left in it a ſulphureous ſmelling ſubſtance, which, when dried, weighed one fourth of a grain. This ſubſtance, when burnt on a red-hot iron, had not a blue, but pale-red flame, and a very gentle ſmell of burnt ſulphur. As this is a vegetable ſulphur, that is to ſay, an inflammable body joined to a vegetable, and not a mineral acid; it probably differs from the mineral ſulphur in the ſtrength of its qualities, and, therefore, may not have ſuch a ſtrong ſmell as the latter.

Let us try if we can aſcertain the quantity of this ſulphureous matter in the decoction. It is very volatile, and therefore cannot be caught, ſo that we might weigh it. Let us take its power in colouring ſilver, and ſee what light it will afford us in this intricate ſcrutiny. The leſs the quantity of ſulphur, the weaker the colour. I took 3 gr. of ſulphur, opened by an alkaline ſalt, and diluted it ſo with water, that the ſolution had loſt all taſte, and took two hours to alter the colour of ſilver in a ſmall degree. The quantity of water uſed was five pints. When two pints more were added, it loſt altogether this quality. To apply this experiment to the preſent queſtion,

Exp. 39. I diluted a ſmall quantity of the decoction, ſo that it took the ſame time to have the ſame effect, as in the former trial. The proportion of water to the decoction was, as 192 to 1. There was three pints of the whole; therefore 192 multiplied by 3, gives the quantity that could be made out of the whole decoction of this weak ſulphurated mixture, which is 576 pints. So that dividing the number

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of pints by 5, and then multiplying them by 3, we have the number of grains of ſulphur in this decoction. The whole then is 5 dr. 35 gr. and about a half, in the decoction, beſides what remains in the reſiduum, which ſeems to be more. Every bleacher, if he extracts all the ſalts from the *Caſhub* aſhes, muſt have that quantity of ſulphur from each half-pound of the aſhes; and if he boils them longer, he will probably have more. The only objection to this reaſoning is, That we have argued from a mineral ſulphur to a vegetable one, and ſuppoſed their powers of tinging ſilver to be the ſame. As I cannot poſitively aſſert them to be the ſame, I muſt allow this objection to have ſome weight; though it is probable there may be little difference betwixt them in this quality.

When the decoction was boiled into a gill and a half, it did not turn ſilver black more ſpeedily than before boiling; which ſhows the ſulphur to be as volatile as the water. This quantity ſtood for ſome days in a cellar, but no ſign of any cryſtalliſation.

It was boiled into a gill, and ſet by again. After ſtanding twelve days, I looked to it, and found it gellied. This was evaporated, and gave me 10 dr. of a brown ſalt, that had a ſtrong alkaline cauſtic taſte. By another experiment, in which the ſalts were ſeparated by cold water, I got a ſmall quantity of a neutral ſalt, like the vitriolated tartar, from theſe aſhes.

Exp. 40. The alkaline ſalt, tried with the acid mixture, efferveſced, and conſumed four and a half tea-ſpoonfuls of it. Thus we find the antacid power of the ſalt is much weaker, than that of the aſhes.

I had two reſiduums, one left in the pot, and another in the brown paper, of a blackiſh colour; both which weighed 5 oz. 7 dr. The loſs in boiling, then, amounts to 7 dr.

Exp. 41. On 1 dr. of the reſiduum powdered I poured the acid mixture. An efferveſcence aroſe; the whole turned very black, ſent up a ſtrong ſulphureous ſmell, and

and tinged the piece of ſilver black. Twenty tea-ſpoonfuls of the acid were conſumed. After the ſaturation there was ſome of the earthy part of the reſiduum at bottom; above it lay a black ſtuff like tar; then the liquor, which was now pellucid, though it was not ſo all the time of efferveſcence. A black ſcum remained on the top till next morning, which then fell to the bottom on ſtirring. What remained in the paper, when the liquor was ſtrained, weighed half a drachm. The liquor being almoſt evaporated, was ſet to cryſtallize.

After ſtanding ſome time it was gellied. Being evaporated over a ſlow fire, it gave me 44 gr. of a pale-red ſaline ſubſtance, but no cryſtals. This ſaline ſubſtance attracted the moiſture ſo ſtrongly, that it could hardly be dried, unleſs put in a ſtrong heat; and, when taken from the fire, turned immediately wet again. It ſeemed to agree pretty much with the ſaline ſubſtance that I ſpoke of before, compoſed of lime and ſpirit of nitre.

Exp.

Exp. 42. Some *Caſhub* aſhes powdered, and often waſhed with water, ſo that the ſalts were all carried off, were infuſed in water. After ſtanding ſome time, I had a weak lime-water, that had ſtill ſomewhat of a ſaline taſte, and had no pellicle.

Exp. 43. Some of the reſiduum was put into a reverberatory furnace for two hours. After that it afforded me a good lime-water. *Caſhub* aſhes, then, appear to contain an earth half vitrified, ſome lime, alkaline ſalts, and a ſulphureous, inflammable, volatile ſubſtance.

LET us inquire whence ariſes the ſulphur of theſe aſhes, of what ſort it is, and what are its effects. Sulphur is a compoſition of the acid of vitriol, and an oil. Any kind of oil will ſerve, whether vegetable or mineral, and make no difference in the compoſition; but no acid will do except that of vitriol. The acid of moſt trees ſeems to be of the vitriolic kind. When they are burnt, the fire diſpels all the watery parts, with ſome of the acid, and the

the more volatile oils; while the remaining acid, more concentrated by loosing the watery particles, unites with the heavy oils, and so forms a sulphur; which remains in the ashes, if the fire is not sufficiently strong, or not continued long enough to consume it; for all charcoal, if fused with alkaline salts, discovers a sulphur. It is remarkable, that charcoal does not tinge silver when rubbed on it, nor shows any other of the effects of sulphur, until it has been opened by an alkaline salt. All these materials are found in the *Cashub* ashes; and therefore no wonder that they contain a sulphur.

But does this vegetable appear to be the same with the common mineral sulphur?

HOMBERG has given us a division of sulphurs into the vegetable, the animal, the bituminous, and the mineral; and has misled many by it. That *Homberg* means the inflammable principle by the word *sulphur*, appears from these words. *L'huile de la plant,*

plant, qui eſt leur matiere ſulfureuſe *.—He was to blame, as well as moſt of the chymiſts have been, for the vague uſe of that word. That diviſion, therefore, cannot affect the preſent queſtion.

It is plain that common ſulphur may be made as well with a vegetable as with a foſſil oil. The acid of vegetables ſeems to be of the ſame nature as that of vitriol; for with the acid of ſome vegetables and the ſalt of tartar, a tartarus vitriolatus ariſes; and with iron or copper, a vitriol of theſe metals. The acid of many plants ſeems to differ from that of vitriol, only becauſe the former is weaker than the latter. It would appear, therefore, that vegetable ſulphur would no wiſe differ from mineral but in being weaker.

The effect of this ſubſtance upon cloth is to diſcolour it; as every bleacher knows, if he uſes a lye of kelp aſhes, or any other ſort of aſhes much impregnated with ſulphur,

* *Mem. de l' acad. des ſcienc.* 1702.

phur, when the cloth has attained a confiderable degree of whitenefs. Let none, however, imagine, that this fulphureous fubftance tinges linen, as much as it does filver. This is an effect peculiar to that metal. Sulphur, when mixed with alkaline falts, is foluble in water, and may in that ftate be taken out of the cloth by mill-wafhing. But if the alkaline falts are feparated from the fulphur, by their ftronger tendency to folution, by their tranfmutation into an abforbent earth, by meeting with an acid in the water thrown on them, or in the operation of fouring, the fulphureous matter, freed from its alkaline diffolvent, will be precipitated on the furface of the cloth; nor will water have the leaft effect in removing it. A pure lye would again diffolve this fulphur; but the continuation of an impure one muft increafe its quantity. Hence the neceffity of a greater evaporation, and longer expofition to the fun and winds; the only method left, during the ufe of a foul lye, to carry off thefe colouring fulphureous particles.

SECT. V.

Marcoft aſhes.

THE *Marcoft* aſhes are of a paler cocour than the former, and have ſome ſmall pieces of charcoal in their compoſition. They have a ſtrong ſaline taſte, with ſo great pungency, that they cannot be held long in the mouth.

Exp. 44. The acid mixture kept up a long fermentation, but not a violent one. A dark-coloured ſubſtance roſe to the ſurface, and likewiſe lay at the bottom on the ſurface of the aſhes. A ſtrong ſulphureous ſmell aroſe; and after ſaturation, which was performed by 13 tea-ſpoonfuls, the liquor had a ſulphureous taſte.

Exp. 45. Half a pound was boiled as the former, and during the ſame time. The decoction was not ſo black as the *Caſhub*, and had not the ſulphureous ſmell. I forgot to try it when turbid; but the ſtrained decoction,

decoction, having ſome of the reſiduum left in the paper mixed with it, had no effect on ſilver.

One ounce, therefore, of *Marcoſt* aſhes was boiled in a pint of water to half the quantity. This decoction coloured ſilver very ſuddenly; and when ſaturated with ſpirit of nitre, let fall a great deal of ſediment. When diluted with 96 waters, it juſt tinctured ſilver. So that the *Marcoſt* ſeems to contain about the half of the ſulphur that the *Caſhub* aſhes do.

The former decoction boiled into two gills, did not tincture ſilver. It appears by theſe experiments, that the ſulphur in this ſalt is much more volatile than the former, and that the whole of it, by continued boiling, may be diſſipated. On this account it ſeems fitter for bleaching. The decoction having ſtood ſome days, and giving no ſign of any other ſalt, was boiled into a gill. This ſet by for twelve days, turned into a gelly. When entirely evaporated, I had of a ſaline ſubſtance 11 dr. 1 ſcrup. and 2 gr.

which added to $5\frac{1}{2}$ oz. of reſiduum, ſhowed the loſs to be 1 oz. 38 gr. By another experiment, in which the ſalts were ſeparated by an infuſion of cold water, I got a ſmall quantity of a neutral ſalt, like the tartarus vitriolatus.

Exp. 46. This ſalt procured by the former experiment, taſtes ſtrongly alkaline; and a half-drachm took 4 tea-ſpoonfuls of the ſaline mixture to ſaturate it. During the efferveſcence I thought I felt a ſulphureous ſmell.

The reſiduum was much of the ſame colour with the aſhes; and is quite inſipid and undiſſolvable in the mouth.

Exp. 47. On 1 dr. of it I poured the acid mixture, which raiſed an efferveſcence much greater than the reſiduum of the *Caſhub*; but did not turn black, nor ſend up a ſulphureous ſmell, nor tinge ſilver. It conſumed 26 ſpoonfuls. After ſaturation, there was a black tar-like ſubſtance reſting on the remaining powder. The liquor, being

ing ſtrained, left 7 gr. of reſiduum. When evaporated, I had 1 dr. 9 gr. of a ſaline ſubſtance, that would not cryſtallize, had a greeniſh yellow colour, and attracted the moiſture ſtrongly from the air. The ant-acid quality, therefore, of the earthy part, is to the ſame quality of the ſaline part, as $3\frac{1}{4}$ to 1.

Exp. 48. To diſcover whether the reſiduum was a calcarious earth, a half-ounce was put for an hour and a half in a reverberatory furnace, during which time it loſt 1 dr. and 1 ſcrup. When put into water, it did not hiſs when mixed; yet next morning I had a ſtrong lime-water, with a pellicle from it.

Exp. 49. To try if I could diſcover any lime in the aſhes themſelves, without the aſſiſtance of fire, I waſhed the ſalts well out with water, after which they afforded me a weak lime-water.

THIS ſalt, therefore, ſeems to contain the ſame principles with the former; only the

the ſulphur is in leſs quantity, and more volatile.

It is proper here to inquire, whether alkaline ſalts produced from different bodies, differ from one another? In examining this fact, chymiſts generally ſtate the queſtion thus: "Have alkaline ſalts any ſpecific dif-"ference?" Almoſt all of them determine in the negative." *Stahl* ſays, Fund. Chym. p. 85. *Nitrum itaque plantarum, cum generali illa oleoſitate craſſa ſeu reſina, conflagrando, in omnibus vegetabilibus, quæ alkali fundunt, unius generis alkali conſtituit.* They allow, that one ſalt is more cauſtic than another, that one is more pure than another; but this, ſay they, is owing to the accidental management of the fire, or the accidental mixture of other bodies. They all allow, that ſalts extracted with tepid water, are not ſo impure, as thoſe with boiling water. The quicker or ſlower evaporation is obſerved to make a difference. But theſe cauſes are ſtill accidental. The *ſoda Hiſpanica* is obſerved to make finer glaſs, than the much purer ſalt of tartar. But this is owing to a mixture

ture of ſea ſalt with the *Spaniſh* kelp aſhes, and a mixture of inflammable matter with the ſalt of tartar. Many other differences are obſerved betwixt the different alkaline ſalts; but theſe, they ſay, are owing to accidental, and not to ſpecific qualities.

Let us underſtand the terms of the queſtion aright, before we argue on it. The queſtion is thus ſtated by *Stahl*. *An ut plantæ, ita etiam earum ſalia fixa, ſpecie et ſpecifico effectu differunt* *? If he means to inquire, whether theſe ſalts have the ſpecific qualities of the plants from which they are got? the queſtion will ſoon be determined in the negative. For the ſalt of poppy enjoys no narcotic quality, nor the ſalt of ipecacuahn an emetic, nor the ſalt of jallap a purgative, nor the ſalt of hemlock a poiſonous. But if he means that one kind of alkaline ſalts have no ſpecific qualities, whereby they differ from another kind, and which the latter, treated the ſame way, may not acquire; and this, by

* Fundam. Chym. p. 85.

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the quotation preceding the laſt, ſeems to be his opinion; I muſt, determined by a variety of experiments made by others, diſſent from ſuch a great chymiſt, and aſſert, that "alkaline ſalts have a ſpecific "difference." Experiment alone can determine this point, and to experiment I ſhall refer the deciſion.

The alkaline baſe of ſea ſalt is found to enjoy ſome particular properties, which no other alkaline ſalt has. It cryſtalliſes like the neutral ſalts. It does not turn moiſt in the air; but, on the contrary, loſes that water which cryſtalliſed along with it, and, of courſe, its tranſparency. When it is combined, and ſaturated with the vitriolic acid, it forms Glauber's ſalt; a ſalt differing in the figure of its cryſtals, its eaſy ſolution in water, and fuſion in the fire, from vitriolated tartar, or a ſalt made of the ſame ſpirit of vitriol and the ſalt of tartar. When it is ſaturated with the ſpirit of nitre, there ariſes a neutral ſalt, differing from nitre, as it powerfully attracts humidity; and its cryſtals are of a quadrangular figure.

HOFFMAN

HOFFMAN, in his 29th obfervation, has fhown us how differently experiments fucceed with different alkaline falts. The alkaline falt of nitre prepared with charcoal, exhaled the fmell of *aqua fortis* on an effufion of fpirit of vitriol; which falt of tartar, or potafhes, do not; owing perhaps to fome of the fpirit of nitre that is not difpelled by the deflagration. If powder of charcoal is added to falt of tartar, or potafhes in fufion, a fort of *hepar fulphuris* is formed; but this does not fucceed with the alkaline falts made of nitre and charcoal, or nitre and the regulus of antimony. Salt of tartar, made with or without nitre, differs from the lixivial falts; for, on an effufion of oil of vitriol, a fetid fmell arifes, a black fcum gathers on the top, and the whole mixture at laft gains the fame colour. The falt made of two parts nitre and one of the regulus of antimony, affords a red tincture with fpirit of wine; which a falt formed of two parts of nitre and one of tartar, or the common potafhes, do not. Thefe fpecific differences in the falts of the two laft experiments, feem to be owing to fome of the oily or ſulphureous particles, which ſtill lurk in them, notwithſtanding all the fire they have ſuſtained.

It appears, then, from theſe experiments, that alkaline ſalts prepared in the common way, from different ſubſtances, are ſpecifically different; and probably have different effects when taken into the human body; but theſe effects are ſo gentle, and ſo maſtered by the alkaline property common to all, that they paſs unobſerved. The fire at length ſeems to diſſipate theſe ſpecific properties, and to reduce the different alkaline ſalts, freed from heterogeneous particles, to one ſimilar nature. The purer theſe ſalts are, ſo much the fitter are they for the uſes of bleaching. The effects of the ſulphur in the *Caſhub* and *Marcoſt* aſhes, have already been explained. The great quantity of ſea ſalt which is in kelp aſhes, may render them unfit for bleaching. But this ſtill ſtands in need of further proof. I do not think that any other ſmall differences betwixt theſe alkaline ſalts can affect their operation on cloth; be-

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caufe that depends entirely on their alkaline property, which can only differ in degree.

S E C T. VI.

Method of manufacturing thefe afhes at home.

ALL reafoning and experiment ought to be connected with the affairs of mankind; and the clofer this connection is, the more valuable thefe efforts of the human mind become. It is by this confideration alone their value ought, and will be meafured. But what can touch us more nearly than the improvement of our manufactures, on which the riches of our country, and the daily bread of the greateft number of its inhabitants depend? With this view, then, I fhall endeavour to make the foregoing experiments more ufeful, and adapt them to the advancement of bleaching, by difcovering how we may make thefe afhes, at a much cheaper rate, amongft ourfelves, while we employ our

 own

own hands, and thereby ſave the nation much money. By ſhowing how theſe aſhes may be compounded, we ſhall be able to give the preceding concluſions their full conviction.

The blue and white pearl aſhes we have diſcovered to be pure alkaline ſalts, without any conſiderable mixture of heterogeneous bodies. Their purity ſhows the lixive to have been ſtrained through ſome cloſe ſubſtance, ſuch as linen, or flannel. The blue aſhes ſhew, by their colour, that they have ſuſtained the moſt fire. But both of them are ſo much alike, that the one may be ſubſtituted for the other; and therefore we ſhall conſider them in one view.

Every one knows, that alkaline ſalts, ſuch as theſe, are got from all plants except the alkaleſcent, and from all trees except the moſt reſinous, which afford them in very ſmall quantity. Theſe plants, or trees, when found, are pulled or felled in the ſpring, dried, and burnt to aſhes. By the effuſion of warm water the ſalts are diſ-

ſolved,

ſolved, and, by ſtraining, ſeparated from the earth along with the water. This ſaline liquor, which is called a lixive, is evaporated over a fire; and what remains, is an alkaline ſalt of the ſame kind with the pearl aſhes.

I was informed by a ſkilful bleacher in *Ireland*, that he practiſed a more expeditious way of extracting the ſalts. He bought the aſhes of different vegetables from the commonalty for 9 *s.* a-buſhel. From theſe a very ſtrong lye was made, into which dry ſtraw was dipped, until it ſucked up all the lye. This ſtraw was afterwards dried and burnt, and gave him ſalts which he ſhowed me, almoſt as good and pure as the pearl aſhes. This method I have ſeveral times tried; but could never burn the ſtraw to white aſhes, the ſalts diminiſhing the inflammability of the ſtraw. It is a very expeditious method, if it can be practiſed. But I can ſee no occaſion for bringing the lye into a ſolid form, as the ſalts muſt again be diſſolved in water before they can be

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ufed. The ftrength of the lye can eafily be determined by the hydroftatical balance.

Though I make no queftion, that the quantity of falt, in plants of the fame fpecies, will vary in different foils and climates; yet it would be of advantage to have the proportion afcertained in general. Some trials of this kind I have made.

Exp. 50. Two pounds of fern which had been pulled *Auguft* 16. were dried, and burnt to white afhes. Thefe weighed 7 dr. and tafted very falt. When lixiviated, ftrained, and evaporated, they gave me 49 gr. of falt, about the eighth part of the afhes. If the fern had been pulled in *April*, it would have afforded more falt. Why then fhould we not prepare falts from this vegetable? There is more of it growing on our hills, than would ferve all our bleachfields. The *Irifh* make great ufe of it.

Exp. 51. From 11 oz. of tobacco afhes I had 1 oz. of falt. Two oz. of peat afhes afforded half a drachm of falt. Nettles, I

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am informed, afford much ſalt. Furz and broom, natives of this country, are very fit for this purpoſe.

BUT the kelp, as it grows in ſuch plenty along our ſhore, and contains more ſalts than any other vegetable I know, would be the moſt proper, were it not for a mixture of ſome ſubſtance that renders it unfit for bleaching, at leaſt of fine cloths, after they have attained a tolerable degree of whiteneſs. It is obſerved by bleachers, that, in theſe circumſtances, it leaves a great yellowneſs in the linen. As theſe aſhes are much uſed in *Ireland*, and as it is not uncommon to bleach coarſe cloths with them in *Scotland*, a diſquiſition into their nature, and ſome attempts to purify them, may not be improper. There are no aſhes ſold ſo cheap as theſe; for the beſt gives but 2 *l.* the 2000 weight. They may, therefore, allow of more labour to be expended on them, and come cheaper at long-run than the foreign ſalts.

Exp. 52. I dried ſome ſea-ware, and burnt it, it, though I found that laſt operation very difficult. When I had kept them fuſed in the fire for two hours, they weighed 3½ oz. I poured on the aſhes an *Engliſh* pint and a half of cold water, that I might have as little of the ſulphur as poſſible. This lye, after it had ſtood for ſome hours, was poured off clear, and had but a ſlight tendency to a green colour. I made a ſecond infuſion with milk-warm water, and poured it off from the ſediment. This had a darker colour than the former, was kept ſeparated from the former, and evaporated by itſelf. There was a third infuſion made; but having no ſalt taſte, it was thrown away. The ſecond infuſion ſeemed to contain more ſulphur than the firſt; and a piece of white linen kept in it half an hour, while it was boiling, was tinged yellow, and could not be waſhed white again. The earthy part remaining, weighed, when well dried, 1 oz. 2 dr. The ſaline decoction, evaporated by degrees, and ſet at different times in a cellar to cryſtallize, afforded me 5 dr. 46 gr. The liquor, when entirely evaporated, left 4½ dr. of a yellow

ſalt,

ſalt, which appeared to be a ſtrong alkaline. The ſalts which cryſtalliſed ſeemed to be moſtly ſea ſalt, with a conſiderable quantity of ſulphur, and ſome alkaline ſalt. There appeared no ſigns of the bittern in theſe ſalts, as their ſolution did not turn turbid with the oil of tartar. Nor was any of the bittern to be expected in kelp aſhes, although it probably is to be found in the recent vegetable; becauſe the alkaline ſalts formed by the fire, muſt have changed it into a neutral. The lye made with warm water, being evaporated, left 4 dr. of a black bitter ſalt, which, from its quantity of ſulphur, appeared unfit for bleaching. Theſe aſhes, then, ſeem to be a compoſition of ſomewhat leſs than the fourth of ſulphur, the ſame quantity of ſea ſalt, about a fourth of alkaline ſalt, and ſomewhat more than a fourth of earth. The alkaline ſalt contained in kelp aſhes, amounts to one penny a pound. This cheapneſs makes it worth our pains to beſtow ſome labour on them.

If the bad effects in bleaching with kelp aſhes ariſe from the ſea ſalt, as ſome of the moſt knowing bleachers think, they can be freed from it in an eaſy manner. Let a lixive of kelp aſhes be made with cold water, for that does not extract ſo much of the ſulphur; it muſt ſtand but a ſhort time, for theſe ſalts diſſolve eaſily; decant it, and evaporate the lye. As the boiling continues, the ſea ſalt will cryſtallize. When that is all ſeparated, the remaining lye will contain alkaline ſalt with ſome ſulphur. This operation every maſter of a bleachfield may learn and overſee, without taking up much of his time. A ſimilar proceſs is carried on by common ſervants in the allum-works, who have by practice learned it from others.

I had ſome hopes that the ſulphur might be carried off by long roaſting, ſuch as theſe ſalts undergo, before they are fuſed, in order to be turned into glaſs; becauſe I had obſerved, that the longer time they were kept in the fire, the freer were they from this ſulphureous part.

Exp. 53. I ordered a quantity of kelp aſhes to be kept in the furnace of a glaſs-

houſe,

houſe, where the heat was juſt below the vitrifying point, for twenty-four hours. During this time they had loſt almoſt four fifths of their weight. They were now much freer from their ſulphur, and were of a light colour; but much of the alkaline ſalt had been driven off with the oils. If a lye is much impregnated with this ſulphureous matter, it appears to be carried off, in a great meaſure, by long boiling.

If we cannot get theſe alkaline ſalts at home in ſufficient quantity, our plantations are ready to afford them, if we are not wanting in induſtry. Our colonies would gain health and riches by the traffic, and we ſhould be provided more certainly, and at a much cheaper rate. The hiccery wood, we are told, affords great plenty of this ſalt. The only way to ſet on foot ſuch a trade as this, would be to ſend from this people ſkilled in the manufacture, with ſuch proper encouragement, for a certain number of years, as the wiſdom of parliament ſhall think fit.

We come now to explain the method of manufacturing the white *Muſcovy* aſhes. We have ſhown, by undoubted experiments, that the greateſt part of theſe aſhes conſiſts of lime; and yet we have ſeveral acts of parliament which forbid the uſe of that material under ſevere penalties. The parliament were in the right to diſcharge its uſe, upon the diſadvantageous reports which were made to them. We ſhall immediately ſee, how dangerous a material it is when uſed improperly, or without the mixture of alkaline ſalts, which render it ſafe, and more ſoluble in water. But I'll venture to ſay, that experiment will not ſupport the prejudice entertained with regard to it, if carried any further.

Since bleaching, then, cannot be carried on without it; for thoſe aſhes which contain it, are quite neceſſary in that operation; and ſince we import them from foreign countries; let theſe prejudices againſt it ceaſe; and let us only conſider how we may render our own lime as ſafe as the foreign. If we can do that, the wiſdom of the legiſ-

lature

lature will be as ready to abrogate theſe acts, as they were to make them.

By my experiments on the white *Muſcovy* aſhes, I got about the eighth part of alkaline ſalts from them. This made me expect, that, by mixing in the ſame proportion quick-lime and alkaline ſalts, I ſhould be able to produce *Muſcovy* aſhes.

Exp. 54. To an ounce of quick-lime and a drachm of white pearl aſhes, I added about a gill of water, and boiled them together till the water was all evaporated. The taſte of this ſubſtance was little different from lime. To recover the ſalts again from the lime, I diſſolved it in water, ſtrained off the liquor, and evaporated it. Inſtead of the drachm of ſalts, I had but 2 gr. of a ſubſtance which was more earthy than ſaline.

Exp. 55. To 3 dr. of quick-lime, and as much potaſhes, I added a mutchkin of water, and kept it boiling for two hours till it was evaporated. I diſſolved it again in

water,

water, which being filtered and evaporated, gave me 1½ dr. of a cauſtic ſalt, that liquified in the air, when it had been but four minutes from the fire. It appears, then, that the alkaline ſalts are deſtroyed by lime, and that a great part of them can never be again recovered. They muſt be reduced to an unſoluble ſubſtance. From the remaining lime, after the ſalts were extracted, I got ſtrong lime-water, but without a pellicle. This ſhows, that a quantity of alkaline ſalts, equal to the lime, boiled with it for two hours, are not able to fix all the ſoluble part of the lime.

From theſe experiments we may draw ſome corollaries with regard to the preſent ſubject. *1ſt*, That evaporating the water from the lime and ſalts by boiling, is a moſt unfrugal way of preparing theſe white aſhes. *2dly*, That theſe aſhes ought to be kept cloſe ſhut up in caſks; for if expoſed to the open air, though in a room, the alternate moiſture and drought muſt fix their moſt uſeful parts. This I have found to be fact; for the ſalts that I made, became leſs

pungent

pungent by keeping; and I have obſerved, that the ſurface of the *Muſcovy* aſhes loſt all pungency, by being expoſed to the air, while their internal parts ſtill retained it. 3*dly*, That all boiling is prejudicial to theſe *Muſcovy* aſhes, as it fixes, and that quickly, their moſt ſubtile, and probably their moſt ſerviceable parts.

Let us now proceed to another method of making theſe white aſhes. I imagined, that if the ſalts were diſſolved in water, and the quick-lime ſlaked with that, the maſs would ſoon dry without the aſſiſtance of fire. In this way I added equal parts of both; but the compoſition was ſo ſtrong, that it bliſtered my tongue, if it but touched it. When the fourth part was alkaline ſalt, it bliſtered my tongue, when kept to it a few ſeconds. I could taſte the ſalts plainly in the compoſition, when they made but the thirty-ſecond part of the whole.

I thought, when compoſed with the eighteenth part of ſalt, it had, when freſh made, juſt the taſte and look of the *Muſcovy*

covy aſhes; nor could any perſon have diſtinguiſhed them. This I once imagined was the proportion; but when I found that the ſaline pungency ſoon turned weaker by keeping, and that this compoſition would not afford the ſame quantity of ſalts that the *Muſcovy* aſhes did, I ſaw that a much greater quantity of ſalts was neceſſary. The proportion appears to be one of ſalt to four of lime, prepared in the laſt way. Three drachms of aſhes prepared in this way, and kept for a fortnight, gave me but 15 grains of ſalt; which is but the half of what the *Muſcovy* would have afforded. I find, if the quick-lime is firſt quenched, it does not fix the ſalts ſo much; and therefore is better, and cheaper. One drachm of potaſhes diſſolved in a little water, and added to 3 drachms of quenched lime, gave me 44 grains of a very cauſtic ſalt. I prefer this method as the beſt.

The manufacturers of this ſalt probably pour the lixive upon the lime, as they can know by its ſpecific gravity what quantity of ſalts is in the water, and ſo ſave themſelves

themſelves the expence of procuring the ſalts in a dry form.

There is now only one proof wanting to ſhow, that theſe are as good as the foreign *Muſcovy* aſhes, *viz.* their anſwering as well in the bleachfield. I ſent ſome that I had made to Mr *John Chryſtie*, and had the following account of their effects in the bleachfield. "The ſmall parcel of aſhes "which I got from thee, appear to be "very good, and in all reſpects anſwer the "purpoſes of the *Muſcovy* white or blanch "aſhes. They are juſt what goes by "the name of *Riga Muſcovy* blue aſhes; "which are the beſt of that kind. I am "ſo well ſatisfied of their anſwering, that "if thou can furniſh me with a parcel "next ſeaſon, I ſhall take them; and doubt "not of bleaching my cloth full as well "with them, as with thoſe brought from "abroad."

The manufacture of the *Marcoſt* and *Caſhub* aſhes remains yet to be explained. We have diſcovered, that both of them contain ſulphur, earth, alkaline ſalts, and lime; and differ in nothing, but in the *Caſhub*'s having more ſulphur than the *Marcoſt* aſhes. We ſhall therefore conſider them together.

WHETHER theſe two ſpecies of aſhes are of any uſe in bleaching, may, and has already been diſputed. I find they contain no other principles, the ſulphureous part excepted, than the former aſhes combined together. Why then ſhould we expect any other effects from the ſame ingredients in the *Marcoſt* and *Caſhub* aſhes, than what we have from either of the pearl and *Muſcovy* aſhes mixed together? The ſulphureous principle in the former muſt have very bad effects; as I find by experiment, that it leaves a yellowneſs on cloth, that is very hard to be waſhed out. It is owing to this ſulphureous principle, that linen, after it has been waſhed with ſoap, and is pretty well advanced in whiteneſs, is apt to be diſcoloured by lye if brought to boil: for by boiling the ſulphureous part is extracted from theſe aſhes, and the lye becomes of

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a deep brown colour. Daily practice, then, ſhows the diſadvantage of this ſulphureous principle. Beſides, as ſulphur unites itſelf, quickly and firmly, with alkaline ſalts, it muſt weaken, or altogether deſtroy a great quantity of theſe in the *Marcoſt* and *Caſhub* aſhes, and ſo render them of no effect in bleaching. Theſe two reaſons ſeem to me ſufficient to exclude them from the bleach-field; eſpecially as, by increaſing the other materials, we can attain, perhaps more ſpeedily, the ſame end.

However, as cuſtom has introduced them into general practice, we ſhall conſider how they are to be manufactured. Dr *Mitchell* has, in a very ingenious and uſeful paper, contained in the *Philoſophical Tranſactions* for the year 1748, delivered an account tranſmitted to him by Dr *Linnæus*, of the method of making potaſhes in *Sweden*. This account was contained in an academical diſſertation of one *Lundmark* upon this ſubject at *Aboe* in *Sweden*. The ſubſtance of this account is, "That birch "or alder is burnt by a ſlow fire to aſhes,

" and made into a paſte with water. This
" paſte is plaiſtered over a row of green
" pine or fir logs. Above that is laid,
" tranſverſely, another row of the ſame;
" and that likewiſe is plaiſtered over. In
" this way they continue building and
" plaiſtering, till the pile be of a conſider-
" able height. This pile is ſet on fire;
" and whenever the aſhes begin to run, it
" is overturned, and the melted aſhes are
" beat with flexible ſticks, ſo that the
" aſhes incruſt the logs of wood, and be-
" come as hard as a ſtone." This, in the Doctor's opinion, is the method of making the potaſhes that come from *Sweden*, *Ruſſia*, and *Dantzick*: and that there is no other difference betwixt the aſhes made in thoſe different countries, but that the *Ruſſian*, containing more ſalt, muſt be made into a paſte with a ſtrong lye.

There would appear, by my experiments, a greater difference than this, betwixt the *Swediſh* aſhes, if that is the true proceſs, and thoſe I have examined. I had diſcovered the greateſt part of the *Muſ-*

covy

covy ashes to be lime. I suspected it might enter into the composition of the *Marcost* and *Cashub*; and have accordingly discovered it there. Without the same grounds, none would ever have searched for it. Whence then comes this lime? It must either enter into its composition, or arise from the materials managed according as the process directs. Let us examine this question thoroughly, as it is a question of great moment, and nearly concerns the manufacture of these salts.

There are two passages in chymical authors, that would induce one to believe a very caustic substance might arise from the terrestrial part of vegetables fluxed with the saline. Thus *Junker*, *Cineres ligni bitulini recentes, et per cribrum trajecti, si aqua humectantur, et globi, instar pomorum, exinde conficiantur, dum æstu intensiore globi exsiccantur, postea igni ejusdem ligni flammante candesiunt, denique adhuc calidi aqua pura coquuntur; lixivium filtratum, et ad consistentiam saturati lixivii evaporatum, adeo acre redditur, ut lanam injectam in mucum resolvet*;

vet; ſulphur quoque brevi ſolvere ſoleat, licet in frigidum lixivium conjiciatur. The other quotation is from *Stahl. Cauſticum fit alkali maritatum cum terra ſua propria, cinere pingui, ſi cineres ex lignis nitroſis,* e. g. *bitulino, leviter humectati, denuo urantur flammeo igni, ſal deinde mox elixetur et coaguletur* *. Both theſe chymiſts, I believe, have formed this opinion, on diſcovering the cauſtic effects of theſe *German* aſhes; but have taken the proceſs of making them on the faith of others. There is no perſon who has dealt in chymical operations, but muſt have found the effect of his experiments very different from what the chymiſts made him expect. I have often been deceived; and therefore ſuſpend my belief till my own experience can determine my opinion. I have tried the birch aſhes made into a paſte with water. I have tried common charcoal, made into a paſte with a third part of potaſhes, and kept them in a ſtrong reverberatory heat for ſome hours, and yet no ſuch cauſtic ſubſtance appeared.

* Vid. Stahl ſpecim. Buchan. p. 11. ſ. 1. m. 1. N° 58.

I have kept the earth and ſalts of kelp aſhes fuſed together for twenty-four hours in the furnace of a glaſs-houſe, where the heat was but juſt below the degree of vitrification; and yet no remarkable cauſticity appeared, afterwards, in the concreted maſs. But ſuppoſing that there did, will ever this account for the generation of lime? Theſe chymiſts do not aſſert that it is a calcarious cauſticity. The earth of vegetables kept in fuſion with their ſalts, is ſo far from turning into a quick-lime, that the maſs takes the oppoſite courſe, and becomes glaſs. Bodies that, by the laws of nature, are vitreſcible, can never, ſo far as we know, become calcarious. In one or other of theſe two ſubſtances all bodies terminate, that are changeable by fire; and vegetables are of the former kind. Here it may be aſked, Why then, ſince they endure ſuch a fire, are they not vitrified? The objection would be juſt, did they contain nothing elſe but what was found in vegetables. But if we once allow, that lime is one of the materials, the difficulty is eaſily ſolved: for lime, we know, in proportion as it is mixed, hinders

ders the vitrification of all bodies. In effect, the earthy part in theſe aſhes is almoſt vitrified; and I think that I have carried the vitrification yet farther in that part; but I never was able, with the utmoſt heat of a reverberatory furnace, continued for ſix hours, to produce any thing like a thorough vitrification in theſe aſhes. The heat of the fire uſed in the proceſs, would ſeem to be very great; and muſt, if it were not very difficult, reduce them to glaſs. The invitreſcible nature of theſe ſalts, ſo far from being an objection, becomes a ſtrong proof of my opinion.

These ſalts have a remarkable pungency. This we have already ſeen is the natural effect of quick-lime on ſalts.

These ſalts are found to be the fitteſt for making ſoap, and to incorporate ſooneſt and beſt with oils. Salts, we know, of themſelves do not readily unite with oil; but when once mixed with quick-lime, they have a greater tendency to union.

Again,

Again, I find that theſe aſhes are more eaſily fluxed than charcoal made into a paſte with the third part ſalt; which is much more than theſe aſhes contain. Now, it is obſerved, that quick-lime increaſes the fluxing power of alkaline ſalts; for the common cauſtic made of quick-lime and alkaline ſalts, is ſooner fuſed than the latter alone.

From theſe reaſons, and the experiments that diſcover lime in theſe aſhes, I am led to think, that it is not generated by the proceſs, but mixed with the aſhes when they are made into a paſte. The following experiment is a convincing proof of what I have been endeavouring to make out.

Exp. 56. I boiled ſome peaſe ſtraw in a ſtrong lye of pearl aſhes, burnt it into a black coal, and made it into a paſte with water. Another quantity of ſtraw was boiled in a lye made of one part quick-lime, and four parts pearl ſalts, the lye being poured off turbid from the lime. This ſtraw was likewiſe burnt when dry, and made into a paſte. Theſe two ſubſtances were put into ſeparate crucibles, and fluxed in a reverberatory furnace. The latter appeared to reſemble the *Marcoſt* and *Caſhub* aſhes, more than the former, which ſeemed to want their pungency.

Long after I was ſatisfied this was the way of manufacturing theſe northern aſhes, I accidentally met with an obſervation of a knowing bleacher. Mr *Chryſtie* ſays, that he was told by Mr *Robert Douglas*, who had been in *Ruſſia*, *Sweden*, and many other parts, that he had ſeen the following method of making aſhes practiſed. " The " aſhes of burnt wood or weeds were mix- " ed with quick-lime, put into a fat or re- " ceiver, and a very ſtrong lye was drawn " from them by water, juſt as bleachers " make their lye. In this lye dried wood " or weeds were ſoaked, until they would " imbibe no more, and then burnt in ovens " prepared for that purpoſe. Theſe ovens " had a ſtrong draught of air, which made " the fire burn moſt furiouſly; and as the " wood was fluxed in the fire, it fell

" through

" through the grate, and run into hard " lumps." Theſe aſhes, by this deſcription, appear to be *Caſhub*, or *Marcoſt* aſhes. I would recommend this method as the eaſieſt and quickeſt of manufacturing theſe ſalts at home.

PART IV.

SECT. I.

The natural effects of these ashes, and other bodies, on unbleached cloth.

IT is no wonder, that the art of bleaching has, as yet, made such small advances, when the facts and circumstances are confined to the bleachers alone, and the natural effects of different bodies on cloth are, even to them, unknown. There are two causes, among many, to which the latter ought principally to be attributed. The generality of those who practise bleaching, look on it as a business already brought to perfection; and, being ignorant of natural philosophy, and the experimental method of carrying it on, never imagine the further progress which it could bestow on this art. The other cause which retards the progress of bleaching, is a want of accurate observations on the effects of the different agents which are employed in it. And,

And, indeed, it is impoſſible that theſe obſervations ſhould be made in the common courſe of buſineſs, conſidering how theſe aſhes are mixed together, when uſed by bleachers, ſo that the particular effects of each can never be known; and conſidering how the other operations of this proceſs immediately ſucceed thoſe applications, by which the effects of all are blended together.

To remedy a defect which cannot well be obviated in the bleachfield, I have made a few experiments, in order to diſcover the effects of different ſubſtances on unbleached cloth. As this is but an attempt towards a complete ſet of experiments in bleaching, I hope they will excite others, whoſe proper buſineſs it is, and who have greater opportunities than I of purſuing the like reſearches. They will point out the general method to be followed in making ſuch experiments. However diſagreeable or tedious the plain narration of experiments may appear, there is no other way to arrive at truth; eſpecially in an art where, from a deficiency in theſe, there is as yet but little certainty.

THAT

THAT I may make theſe experiments as accurate and extenſive as poſſible, I ſhall try them with different degrees of heat; with that of the atmoſphere, with a gentle degree of heat, equal to that of the human body, and with the heat of boiling water; for the effects of moſt diſſolvents are increaſed by heat. The cloth uſed in the following experiments, was ſteeped in warm water for a night, to take out the dirt and dreſſing.

Exp. 57. *July* 26. To diſcover the effects of pearl aſhes, I diſſolved 10 gr. of pearl aſhes in 6 oz. of water, and put a piece of unbleached cloth, about 15 ſquare inches, into the ſolution. After it had been in this weak lixive about a minute, a great many air-bubbles aroſe to the ſurface. 28. Ten grains more of the ſalts were added, and more air-bubbles aroſe as before. The lixive had now a ſtrong alkaline taſte. *Aug.* 7. The lixive taſtes much weaker. The cloth appears to have a redder caſt than a piece of the ſame cloth in plain water. Thirty grains more of the ſalts were added.

About

About half an hour afterwards a great many air-bubbles were on the ſurface of the liquor, and many more aroſe on touching the glaſs. 9. I immerſed the glaſs half-way up in warm water, and kept it there for two hours and a half, renewing the warm water. During that time I ſaw no air-bubbles ariſe. 26. The water had no alkaline taſte, and the cloth had a deep red colour. 28. That I might ſee the natural colour of the cloth, and diſcover its degree of firmneſs, I took out the alkaline ſalts, by ſteeping the cloth all night in water acidulated with ſpirit of nitre. I could obſerve no fermentation or inteſtine motion in the liquor. The cloth, being waſhed in warm water, and dried at the fire, appeared much whiter than when it was put into the lixive. I ſhall diſtinguiſh the colours in the following experiments, at this particular time, into four different claſſes, according to their different degrees of whiteneſs, placing the whiteſt in the firſt claſs. According to this diſtribution of colours, the cloth in this experiment was in the third claſs; it ſeemed as firm and ſtrong as at firſt. *Sept.* 9. The cloth was taken out,

out, waſhed with ſoap and water, and dried. There was not ſuch a diſtinction betwixt the colours of the different cloths at this inſpection as there was at the laſt; but ſtill this cloth was inferior in colour to the reſt. 21. There appeared a great ſediment at the bottom of the glaſs. When the cloth was waſhed and dried, it was amongſt the darkeſt-coloured, though whiter than at laſt inſpection. It is ſtill ſtrong. I renewed the water, and added half an ounce of pearl aſhes, to diſcover if theſe ſalts could weaken cloth. *Nov.* 11. The cloth apppears no whiter, and no weaker.

Exp. 58. *July* 26. To diſcover the effects of *Muſcovy* aſhes, I added half a drachm of white *Muſcovy* aſhes in powder, to 6 oz. of water; and infuſed, in this mixture, the ſame quantity of cloth, as in laſt experiment. 28. I added the ſame quantity as before. The cloth juſt begins to whiten. *Aug.* 9. The glaſs ſtood two hours and an half in warm water. 26. The water had ſcarcely any taſte. 28. The cloth was ſteeped all night, with the former, in water acidulated.

acidulated with ſpirit of nitre. When dried, it appeared to be in the ſame claſs of colours with the former. It was remarkably weaker, ſo that I could eaſily tear it, when I could not the former. *Sept*. 9. Waſhed with ſoap, and dried, it now appeared to be in the firſt claſs of whiteneſs; ſtill weaker, but not ſo much as the cloth, in ſhell-lime water. 21. Much whiter, but ſcarcely any weaker. *Nov*. 11. Not ſo white as the cloth in the lime-water, nor ſo weak.

Exp. 59. *July* 26. To diſcover the effect of *Marcoſt* aſhes, I boiled a drachm and a half of *Marcoſt* aſhes for half an hour in 6 oz. of water, adding, at the latter end, as much water as was loſt by evaporation. Boiling is neceſſary to extract the ſalts from theſe aſhes. In this lixive the ſame piece of cloth as in the former, was infuſed. *Aug*. 7. No whiteneſs yet begins to appear; the cloth ſeems rather ſomewhat reddiſh. 9. When the glaſs was put into milk-warm water, as the former were, air-bubbles aroſe. 28. The cloth was ſteeped all night in water, acidulated with ſpirit of nitre. When dried, it appeared in the third claſs as to whiteneſs; it ſeemed conſiderably weaker. *Sept.* 9. Whiter and weaker. 21. Very white, but quite rotten. *Nov.* 11. Scarcely ſo white as the cloth in the two following experiments, but almoſt as rotten. *Caſhub* ſeems, by experiment, to have much the ſame effect as *Marcoſt*, in weakening cloth, but leaves a much redder colour on it.

Exp. 60. *July* 16. To diſcover the effects of lime-water, I infuſed the ſame quantity of the ſame cloth in ſtone-lime water. It ſent up directly a great many more air-bubbles than any of the reſt. *Aug.* 7. The cloth begins to appear whiter. No ſediment to be ſeen. As the lime-water had almoſt loſt its taſte; all the glaſſes being but ſlightly corked, I renewed the lime-water. 9. The glaſs was put for two hours and a half in milk-warm water, during which a few air-bubbles aroſe. 26. Not much whiter than laſt time. A brown

brown ſubſtance at the bottom of the glaſs. 28. Steeped the cloth for a night in water, acidulated with ſpirit of nitre, to take the particles of lime out of it. When dried, the cloth appeared to be amongſt the whiteſt in the third claſs of colours. I did not yet diſcover it weaker. Renewed the lime-water. *Sept.* 9. When waſhed with ſoap, and dried, it equalled the cloth that had been ſteeped in the *Muſcovy* aſhes, and ſurpaſſed all the reſt. It ſeems weaker. 21. It appears now very white, and very tender. Renewed the lime-water. *November* 11. No whiter, but rather weaker.

Exp. 61. *Aug.* 10. That I might diſcover what effect oyſter-ſhell lime-water would have on cloth, as it has a ſtronger power in diſſolving the human calculus than ſtone-lime water, I ſteeped the ſame quantity of the ſame cloth in the ſame quantity of ſhell-lime water. 26. Remarkably whiter, even more ſo than the cloth in the ſtone-lime water, that had been ſteeped double the time. 28. To take out the particles of lime, it was infuſed for a

 night

night in water, acidulated with ſpirit of nitre. When dried, it appeared rather whiter than the cloth of the former experiment, and as much weakened. Renewed the ſhell-lime water. *Sept.* 9. When waſhed with ſoap and water, it appeared whiter, but with a yellowiſh caſt. It was much tenderer than the cloth of the former experiment. 21. Exceeding white, though with a yellow caſt, but quite rotten. *November* 11. No whiter, but very weak.

Exp. 62. *July* 26. That I might diſcover the effects of alkaline ſalts and lime combined together, I ſlaked half a drachm of quick-lime with an equal quantity of pearl aſhes diſſolved in water. In this mixture an equal quantity of the ſame cloth as in the former experiments, was ſteeped. Some air-bubbles aroſe immediately. *August* 1. Some clouds were ſuſpended in the liquor; and a filmy oozy matter was depoſited at the bottom. 7. The cloth appears whiter. The lixive taſtes yet very ſtrong. 9. I added the ſame quantity of lime and ſalts, as the lye was beginning to turn

turn weak. The glaſs was two hours and a half in milk-warm water, during which time many air-bubbles aroſe. 26. The lye taſtes much weaker. 28. Steeped all night in the ſame acidulated water as the former were, and dried. This cloth was now the whiteſt of the whole, though it did not appear ſo before it was ſteeped in the acid. It is therefore to be ranked in the firſt claſs at preſent. Appears to be no weaker. Added to the liquor 5 gr. of the cauſtic ſalt extracted from equal parts of quick-lime and alkaline ſalts, and therefore of the ſame kind with the former. *Sept.* 9. The cloth waſhed with ſoap, and dried. Whiter than before; yet was ſcarcely ſo white as the cloth in lime-water, or that in the *Muſcovy* aſhes. 21. The cloth has now attained a very great degree of whiteneſs, and ſeems no weaker than when it was firſt put into the lixive. *Nov.* 11. As white as the cloth in the lime-water, and as ſtrong as cloth that has been bleached in the ſafeſt way.

Exp. 63. *July* 26. To diſcover what effects lime-water with a few grains of alkaline

line ſalt would have on unbleached cloth, as this would be a cheaper method of bleaching than any of the former, I added to 6 oz. of ſtone-lime water, 10 gr. of blue pearl aſhes. When the ſalts were added, the liquor turned white, curdled as hard water does with ſoap, and in a little a great quantity of white powder was precipitated to the bottom. Into this mixture the ſame quantity of the ſame unbleached cloth was put. 28. The liquor taſted like a weak ſolution of ſoap. *Aug.* 1. A ſmall quantity of a filmy matter appears ſwimming in the mixture. 7. No whiteneſs yet appears. 9. Was two hours in warm water. 26. Taſtes ſtill pretty ſtrong. 28. Steeped all night in the acidulated water, and dried. Appears now in the ſecond claſs of whiteneſs; and though not ſo white as the cloth in the former experiment, yet ſurpaſſing all the reſt. *September* 9. The cloth waſhed with ſoap, and dried. Though whiter than before, yet is not ſo white as that in the lime-water, or *Muſcovy* aſhes. Appears to be no weaker. 21. Is now very white, and a very little weaker. The liquor renewed. *Nov.* 11.

This

This cloth appears as white as thoſe in the ſtone and oyſter-ſhell lime-waters. It ſeems to be no weaker than cloth that has been bleached in the beſt manner.

Exp. 64. *July* 26. To diſcover the effects of oil of vitriol, the ſame quantity of the ſame cloth was put into the ſame quantity of water, to which were added 30 drops of the oil of vitriol. 28. Added 30 drops more. The water has a gentle acid taſte. *Aug.* 1. A white ſediment, or oily-like matter lies at the bottom of the glaſs. 7. The liquor has no acidity. An oozy matter, ſimilar to what was before obſerved at the bottom, is now to be ſeen floating in the liquor, and adhering to the cloth. The colour of the cloth is whiter than a piece of the ſame that had been for the ſame time in water. Sixty drops more were added, and the glaſs is put four hours in milk-warm water; during which a great many air-bubbles aroſe, and the liquor afterwards taſted much leſs acid. Cloth ſtill firm. Sixty drops more added. 14. Covered all over with the oozy oily-like matter.

matter. 25. Appears whiter, with more of that oozy matter. The liquor is leſs acid. The cloth ſtill ſtrong. Renewed the water, and added 100 drops to it. 28. That I might take the acid ſalts out of the cloth, and diſcover its real colour, I ſteeped this cloth, and that of the two following experiments, in a ſolution of alkaline ſalts. I obſerved a fermentation, or inteſtine motion, in the liquor. When the cloth was waſhed and dried, it was much behind thoſe in the foregoing experiments in colour, and but juſt a degree whiter than a piece of the ſame cloth that had been in plain water. It looked whiter when in the glaſs. It muſt therefore be placed in a fourth claſs. This cloth, and the two pieces in the following experiments, felt hard and rough. *Sept.* 9. Waſhed with ſoap and water. It was ſtill much behind the former in colour. As ſtrong as at firſt. *Nov.* 11. Colour and ſtrength the ſame.

Exp. 65. *July* 26. To try the effect of ſpirit of nitre, the ſame quantity of the ſame cloth was ſteeped in the ſame quantity

tity of water, to which were added 30 drops of the ſpirit of nitre. The liquor taſted gently acid. Immediately after the cloth was put in, it was all full of air-bubbles. 28. The air-bubbles ſtill adhering to it. Added 30 drops more. *Aug.* 1. A white ſediment lying at the bottom. 7. Not ſo much of that oily-like matter, which was ſuſpended in the former. Leſs acid than what it was before, and about the ſame degree with that of the former experiment. A ſmall degree whiter than the cloth in plain water, but not ſo white as the cloth in the vitriol. 8. The glaſs immerſed half-way in milk-warm water for four hours. More air-bubbles ariſe from this glaſs than from any of the others. That part of the cloth that was below the ſurface of the warm water, ſeemed, after the glaſs was removed, to be whiter than that above the ſurface. As the liquor taſted leſs acid, 30 drops were added. The cloth ſtill firm. 26. The liquor more acid than the vitriolated liquor in the foregoing experiment. The cloth as white and as ſtrong, but not ſo much of the oozy matter as in that. Renewed the water with 100 drops of the ſpirit. 28. After being ſteeped all night in the lye with the former, it appeared rough and hard, and of the ſame colour with it. *Sept.* 9. After being waſhed with ſoap and water, of the ſame colour as the former. As firm as at firſt. *Nov.* 11. Colour and ſtrength the ſame.

Exp. 66. *July* 26. To diſcover the effects of the ſpirit of ſea ſalt, the ſame quantity of the ſame cloth was ſteeped in the ſame quantity of water, and 30 drops of the ſpirit of ſea ſalt. The cloth was immediately covered all over with air-bubbles. 28. Liquor ſtill acid. Added 30 drops more. *Aug.* 1. This liquor is the moſt acid of the three. A white ſediment at the bottom, but not ſo much as any of the former. 7. More acid than the vitriol, but leſs of the oily-like matter ſuſpended in it. Added 30 drops more. A degree whiter than the cloth in plain water, but ſcarcely ſo much as that in the vitriol. 8. The glaſs was four hours in warm water; during which time many air-bubbles aroſe, and afterwards

terwards the liquor was leſs acid. That part of the cloth that was in the warm water, and had ſuſtained the greateſt heat, was whiter than the upper part. Cloth firm. Added 30 drops. 26. Not ſo white as the former two. No oozy matter at bottom. The liquor very acid. 28. When treated as the former, was as rough, and ſcarcely ſo white. As the glaſs was broke at this time, I added 60 drops to the ſame quantity of water. *Sept.* 21. Whiter, but no tenderer. The liquor is ſcarcely acid. Added 100 drops more. *Nov.* 11. Colour and ſtrength the ſame.

THAT I might ſee what effects plain water had upon cloth, and, by that, more certainly judge of the real effects of theſe alkaline and acid ſalts,

Exp. 67. *July* 26. I put the ſame quantity of the ſame cloth in the ſame quantity of plain water. *Aug.* 1. Water begins to ſmell. A filmy oozy matter at the bottom. 7. Water ſpoiled, ſo renewed. 8. When in the milk-warm water, ſome air-bubbles a-

 roſe,

rofe, but fewer than in the reft. 26. Renewed the water. *Sept*. 9. The cloth had a yellow caft. 21. A very little whiter, but no tenderer. *Nov*. 11. Whiter.

To difcover if foap has any power in whitening unbleached cloth more than removing the dirt on the furface,

Exp. 68. *Sept*. 9. Forty-four grains of the fame cloth was fteeped in 8 oz. of water, in which was diffolved 2 dr. of *Caftile* foap. *Nov*. 11. The cloth was of the fame colour and ftrength as when put in; and, when wafhed and dried, weighed 45 gr.

That I might difcover the effect of fea falt on unbleached cloth,

Exp. 69. *Aug*. 30. I diffolved half a drachm of pure fea falt, without any mixture of the bittern, in 6 oz. of water, and infufed a piece of cloth in it. *Sept*. 21. Cloth a degree whiter, but no tenderer. *Nov*. 11. The cloth appears rather darker than when put in, and is remarkably thinner

ner and weaker. There is much black matter at the bottom of the glafs. As I imagined that thefe effects proceeded in fome meafure from corruption, which is aided by a fmall quantity of fea falt, I repeated this experiment twice, once with 2 dr. and once with 4 to the fame quantity of water. After they had ftood eight weeks, the cloth in each appeared thinner, weaker, and no whiter.

THAT I might difcover the effect of putrefaction on cloth,

Exp. 70. *Aug.* 8. A piece of the fame cloth was put in water. 26. Water much fpoiled, and the cloth very black. 30. The cloth ftill blacker, and fome black matter like foot, has fallen to the bottom of the glafs. There is a pellicle on the furface of the liquor. The cloth, when dried, was no weaker. *Sept.* 9. The water ftunk abominably, and the cloth as black as foot before wafhing, but was not fenfibly weaker. *Sept.* 21. Still black, but no weaker. The quantity of black precipitated matter increafed.

creaſed. *Nov.* 11. The cloth waſhed with ſoap and dried, appears a very little darker, with ſome yellow clouds in it, and is much weakened.

My next experiments were made with a view to diſcover what effect a gentle degree of heat, equal to that of the human body, would have on the action of theſe bleaching materials.

Exp. 71. *Aug.* 10. The ſame quantity of the ſame cloth was ſteeped in the ſame quantity of water, in which 40 gr. of white pearl aſhes had been diſſolved, and ſet ſo near the kitchen-fire, as to keep it in the forementioned degree of heat. 14. The cloth was whiter. 28. Steeped all night in the ſame acidulated mixture with the others, and dried it. Appeared much whiter, and was at preſent next to the cloth in the lime and aſhes of thoſe four experiments made with this degree of heat. *Sept.* 9. Whiter than the following experiment made with the oil of vitriol. 21. Whiter, and ſtill ſtrong. Added 40 gr. more. *Nov.* 11. No whiter, and no weaker.

Exp.

Exp. 72. *Aug.* 10. The ſame quantity of the ſame cloth was infuſed in the ſame quantity of ſtone-lime water, and that the fire might not ſoon evaporate the lime, 2 tea-ſpoonfuls of fine ſlaked lime was added. 14. Begins to whiten. 28. The cloth not ſo white as in the laſt experiment at this time. *Sept.* 9. This was now the whiteſt of thoſe that ſtood at the fire, and much more ſo than the cloth of any of the experiments made without any heat, but is very tender. 21. The whiteſt of the whole, but ſo tender, that it ſeparated with the leaſt force. *Nov.* 11. The cloth is now ſo rotten, that it has fallen all to pieces in waſhing it, and can be reduced, betwixt the fingers, to a powder.

Exp. 73. *Aug.* 10. The ſame quantity of the ſame cloth infuſed in the ſame quantity of water, to which was added 1 dr. of home-manufactured *Muſcovy* aſhes, *viz.* 4 parts of quick-lime ſlaked, with 1 part pearl aſhes and water. 14. Begins to whiten. 28. This cloth was now the whiteſt of all thoſe at the fire. *Sept.* 9. Neither ſo white

nor

nor ſo weak as the cloth in the former experiment. 21. Very white and tender. *Nov.* 11. Quite rotten, though not ſo much as the former.

Exp. 74. *Aug.* 10. The ſame quantity of the ſame cloth in the ſame quantity of water, to which was added 95 drops of the oil of vitriol. 14. Whiteneſs juſt begins to appear. Added 70 drops more. 28. The leaſt advanced of the whole at the fire in whiteneſs. *Sept.* 9. It had now a deep reddiſh caſt. 21. Much whiter, but no weaker. *Nov.* 11. The cloth has got a reddiſh colour, and is no weaker.

LET us now ſee the effect of theſe ſalts when the heat employed ariſes to that of boiling water.

Exp. 75. *Sept.* 11. Three drachms of unbleached cloth, at 13 *d.* a-yard, was put into a pint of water, in which was diſſolved 1 dr. of pearl aſhes, and the water gradually brought to boil. It was kept boiling for five hours, having filled it twice up with water,

water, as the boiling diminiſhed it. When it had boiled two hours, the decoction had no longer any taſte of the ſalts, and was high coloured. When the five hours were elapſed, the cloth was taken out, wrung, and well waſhed in warm water. When dried, it was ſtill firm and ſtrong, and weighed 2 dr. 50 gr.: ſo that it had loſt 10 gr. Being expoſed to the influence of the air all night, and next day, which was very hot and clear, and regularly watered as it dried, the cloth loſt $3\frac{1}{2}$ gr. *Sept.* 13. Boiled as before in a freſh lye, wherein 1 dr. of pearl aſhes was diſſolved. When it had boiled two hours, I added 1 dr. more. Five hours after that 1 dr. more was added. It was removed when it had boiled thirteen hours; at which time the lye taſted ſtrong; waſhed, and dried. The cloth was ſtill firm, had a yellow colour, and weighed 2 dr. 40 gr. So that it had loſt $6\frac{1}{2}$ gr. on this laſt boiling. In order to diſcover what quantity of the ſaline particles remained in the cloth, I ſteeped it in water and vinegar, equal parts, for half an hour. When the cloth was firſt put in, there was a great fer-

 mentation,

mentation, or inteſtine motion, and many air-bubbles aroſe. Waſhed and dried, it was 2 gr. lighter. During the 14th, 15th, and 16th of *September*, it was expoſed night and day, and watered. Waſhed and dried, the cloth weighed 2 dr. 33 gr. *Sept.* 17. The ſame cloth was put into the laſt decoction, as it was yet ſtrongly alkaline, to ſee if theſe ſalts could weaken it. Having boiled eleven hours, it was taken out, waſhed, and dried, and weighed 2 dr. 38½ gr. So that it had gained 5 gr. from the foul decoction. It was now about the ſtrength of cloth that comes from the bleachfield; and though not tender, yet was weaker than at firſt. To carry off the foulneſs and ſalts that it had abſorbed from the lye, and diſcover its real diminution, I put it in vinegar for three minutes. Air-bubbles aroſe. Waſhed and dried, it weighed 2 dr. 30½ gr. I now diſcovered that the laſt boiling had extracted 2½ gr. from it. Expoſed from twelve to ſeven at night in a ſtrong wind, but no ſunſhine, and watered twice, it weighed 2 dr. 28½ gr. *Sept.* 20. The cloth was put into butter milk, that had been well ſkimmed,

and

and soured by boiling with a little water, so that it was now very thin, and as sour as good vinegar. Some air-bubbles arose. 22. The whey no longer sour. 24. The cloth taken out, washed in warm water, and dried, weighed 2 dr. 33½ gr. So that it has gained 5 gr. of additional weight from the butter milk.

Exp. 76. *Sept.* 12. Two drachms fifty-two grains of the same cloth were boiled as the former, with 1 dr. of *Muscovy* ashes, for five hours. When washed and dried, it weighed 2 dr. 46½ gr. The *Muscovy* ashes had been kept by me for four months, and they seemed to me not to be very strong. The colour was like the former. Exposed in a cloudy but warm day, I observed, that when dry, it did not imbibe the water that was thrown on it, but allowed the water to run off as if the cloth had been oiled; and when I thought the cloth was sufficiently wet by watering it, I found the opposite side almost dry. It was exposed for twenty-four hours. When dried, it weighed 2 dr. 43 gr. The cloth was divided into two different pieces, which weighed 1 dr. 21 gr. each. To try what effect *Castile* soap has in the lye, and if it corrects the corroding quality of the *Muscovy* ashes, I put one half, which I shall call N° 1. into an *English* pint of water, to which was added 1 dr. of *Muscovy* ashes; and N° 2. into the same, with an addition of half a drachm of *Castile* soap. After they had boiled two hours, 1 dr. of *Muscovy* ashes was added to N° 1.; and the same, with the addition of half a drachm of *Castile* soap, to N° 2. Five hours afterwards the same addition was made to each. After they had boiled thirteen hours, both pieces of cloth were taken out, washed, and dried. Both pieces were much weakened: if there was any difference betwixt them; N° 2. was most so. N° 1. weighed 1 dr. 16 gr.; N° 2. 1 dr. 18 gr. Both pieces exposed to the air, and watered, for twenty-four hours, then dried, N° 1. weighed 1 dr. 12½ gr.; N° 2. 1 dr. 15 gr. *Sept.* 16. Put both pieces in a pint of butter milk. 24. The milk is whigged, and still pretty sour. Took out both pieces,

washed

washed and dried them. N° 1. weighed 1 dr. 12½ gr.; N° 2. 1 dr. 14 gr.

Exp. 77. *Sept.* 12. One drachm and a half on the same cloth was boiled as the former, with 1 dr. of *Marcost* ashes, for five hours. When washed and dried, it weighed 1 dr. 21½ gr. The cloth was whiter, but had a yellow cast. *Sept.* 13. Laid out to dry at ten *a.m.* in a cloudy day. This cloth, when dry, quickly imbibed the water that was thrown on it. This exposed for twenty-four hours in cloudy weather, seemed the whitest of all the pieces that were boiled. Taken up *Sept.* 16. in the evening, it weighed, when well dried, 1 dr. 18 gr. and was still firm and strong. The cloth was steeped in an acid liquor, consisting of two parts water and one part vinegar. Taken out *Sept.* 18. washed, and dried, it weighed 1 dr. 17½ gr. When boiled in half a pint of water, and 2 dr. of *Marcost* ashes, for thirteen hours, washed and dried, it weighed 1 dr. 12½ gr. The cloth was as strong as at first. Exposed in sunshine, and a good gale of wind, from nine

a.

a. m. to ſeven *p. m.* and watered four times during that time, it weighed 1 dr. 15 gr. The water that I uſed in theſe experiments, was in the ſecond claſs of hardneſs, and might therefore have left ſome particles behind in the cloth, or the wind might have blown ſome duſt upon it. This cloth has now attained a conſiderable degree of whiteneſs, and appears to be a little weaker. Soured in the ſame butter milk whigged, as is deſcribed in *Exp.* 75. for four days, then waſhed in warm water and dried, it weighed 1 dr. 13½ gr. It ſeemed now to have again recovered all its ſtrength.

Exp. 78. *Sept.* 11. Boiled 2½ dr. of the ſame cloth the ſame way as in the former experiments, in an *Engliſh* pint of water, and 50 gr. of quick-lime. After it had boiled five hours, the decoction taſting ſtrongly of lime-water to the laſt, the cloth, when waſhed and dried, weighed 2 dr. 8 gr. ſo that it had loſt 22 gr. of its weight; and if we allow that ſome of the lime might ſtill be in the cloth, it muſt have loſt more. It was evidently thinner, and ſcarcely ſo white

white as the cloth boiled the same time in the pearl ashes. Exposed to the air for twenty-four hours, the day being very clear and very hot, it lost 1½ gr. *Sept.* 13. This cloth was boiled for thirteen hours, adding 50 gr. of lime at proper intervals, as in the former cases. When washed and dried, it weighed 2 dr. 5½ gr. Appeared remarkably whiter, weaker, and was full of white dust, which appeared whenever the cloth was shaked or tore. To discover what quantity of the lime it contained, it was steeped in warm water and vinegar, washed and dried; it weighed 2 dr. 1 gr. It seemed now considerably softer, and thinner, and was not easily wetted by the water which was thrown on it.

Exp. 79. *Sept.* 12. To discover the effect of pearl ashes and lime mixed together, 3 dr. of the same cloth was boiled in an *English* pint of water, and pearl ashes, and quick-lime, half a drachm each, for five hours. The cloth, when washed and dried, had a reddish colour, and weighed 2 dr.

44 gr. Expoſed directly to the air, watered for four days, and dried, it weighed 2 dr. 36½ gr. No weaker. That I might take all the alkaline particles out of it, the cloth was ſteeped in freſh churned milk and water, equal parts, for forty-eight hours. It weighed, when waſhed and dried, 2 dr. 39 gr. It was boiled for thirteen hours in quick-lime and pearl aſhes, 3 dr. each, adding them at proper intervals, as in the former experiments. The cloth, when waſhed and dried, weighed 2 dr. 18 gr. It ſeemed weakened, but not ſo much as in the laſt experiment. *Sept.* 20. Steeped in the ſour whig of butter milk for four days. It weighed, when waſhed and dried, 2 dr. 15½ gr.

To diſcover the effects of pearl aſhes mixed with the *Muſcovy* aſhes as they are in the bleachfield,

Exp. 80. *Sept.* 12. I boiled 3 dr. of the ſame cloth in a pint of water, to which were added 40 gr. of *Muſcovy* and 20 of pearl aſhes, which I computed to be nearly of of the ſame ſtrength as equal parts of quick-lime and ſalts. When it had boiled five hours, was waſhed and dried, it weighed 2 dr. 32 gr. Expoſed to the ſun at two *p. m.* and watered, and taken up *Sept.* 16. in the evening, it weighed 2 dr. 27½ gr. The water did not penetrate it well. No weaker. To ſee if any alkaline particles yet remained in the cloth, it was ſteeped in water and vinegar. When dried, it weighed 2 dr. 23 gr. *Sept.* 24. Boiled for twelve hours in 3 dr. of pearl aſhes and as much *Muſcovy*, adding 1 dr. of each at proper intervals, as in the former experiments; when waſhed and dried, it weighed 2 dr. 39½ gr. The cloth boiled in the quick-lime and pearl aſhes, and that in the *Marcoſt* aſhes, were the whiteſt of the laſt ſix experiments. The other four pieces were pretty much of the ſame colour. The cloth appeared to be much of the ſame ſtrength as that in the laſt experiment.

To diſcover the effects of the mineral acids with a boiling heat, *Exp.* 81. *Sept.* 18. I boiled 42 gr. of the ſame cloth in a half *Engliſh* pint of water, to which were added 2 dr. of the ſpirit of vitriol. After it had boiled five hours, the water was ſtill acid. The cloth, when waſhed and dried, weighed 38 gr.

Exp. 82. To try the effect of ſoap, I boiled 39 gr. of the ſame cloth in half a pint of water and 1 dr. of *Caſtile* ſoap. The water was kept boiling for five hours. The cloth, waſhed and dried, weighed 38½ gr. It had therefore loſt only half a grain during five hours boiling.

To ſee what effect plain boiling water would have on cloth, that I might not attribute what belonged properly to it, to the different bodies that I have been trying,

Exp. 83. Forty-two grains of the ſame cloth were boiled, as the others had been, for five hours in water. When dried, it weighed 41½ gr. It had got ſomething of a yellow colour, and was evidently weaker; for

I tore it, but indeed with ſome difficulty, which I could not do before it was boiled.

Although it is the practice with bleachers to mix ſoap with their lye, yet the neceſſity or utility of it is ſtill a doubtful queſtion. In defence of the common practice, it is ſaid, that the ſoap blunts the ſharpneſs of the ſalts, and makes the lye more ſafe. On the contrary, it is alledged, that making the lye weaker would have the ſame effect, and the ſoap would be ſaved. This queſtion is only to be determined by experiment.

Exp. 84. *Sept.* 11. Forty-five grains of unbleached cloth were infuſed in a pint of lime-water. *Nov.* 15. Cloth is much weakened, and weighs 43½ gr.

Sept. 11. I put the ſame quantity of cloth in the ſame quantity of lime-water, with the addition of half a drachm of *Caſtile* ſoap; which broke in it as in hard water. *Nov.* 15. The ſoap ſtill ſwimming on the top; and the cloth as weak as in the former caſe, but feels ſofter.

Sept. 11. Forty-four grains of the ſame cloth were put in a pint of water, to which were added 2 ſcrup. of *Muſcovy* aſhes and half a drachm of *Caſtile* ſoap. In this the ſoap diſſolved tolerably well. *Nov.* 15. Cloth weaker, and weighs 41 gr.

Sept. 11. Forty-five grains of the ſame cloth were put in the ſame mixture, with the addition of half a drachm of pearl aſhes. *Nov.* 11. The cloth as white as the former; is not weakened, and weighs 42 gr.

IT appears, then, that the corroding power of lime and *Muſcovy* aſhes is not weakened by ſoap.

THAT I might ſee if ſoap had any effect on lime and ſalts mixed in equal quantities,

Exp. 85. *Sept.* 23. Sixteen grains of cloth were put into 2 oz. of water, in which was diſſolved half a drachm of ſalts, that had been procured from equal parts of quick-lime and pearl aſhes. The ſame quantity of cloth was put into another mixture of the

the same kind, with the addition of half a drachm of soap. *Nov.* 15. Both pieces of an equal colour, both strong, and both had lost 1 gr. That in the soap was softest.

I have in these experiments related the facts as they appeared to me, and not the conclusions which may be drawn from them. Experiments, and the reasonings on them, ought, in my opinion, always to be kept separated, that every one may have it in his power to judge, whether the latter naturally and justly arise from the former. Let us now see what aphorisms or corollaries may be fairly drawn from the foregoing experiments. I could wish more of these had been made, that those might have been established with a greater degree of certainty. I endeavoured to supply their number by their accuracy; for these experiments were all repeated a second time. The first accounts of all arts and sciences, have ever been imperfect; that will be excuse sufficient for what failings are met with here. But let it be remembered, that these first rude attempts have pushed on and helped others

others to bring theſe arts to greater perfection.

Corol. 1. Water appears by *Exp.* 67. & 81. to diſſolve ſomething in the cloth, to make it lighter, and to have a power, though a weak one, to whiten cloth. If brought to boil, it would ſeem to have a tendency to weaken cloth. Water, then, may juſtly be ranked amongſt the bleaching menſtruums.

Cor. 2. The mineral acid ſpirits, *viz.* oil of vitriol, ſpirit of nitre, and ſpirit of ſea ſalt, when diluted with a ſufficient quantity of water, extract from the cloth ſomewhat of an oozy ſubſtance, heavier than the acid mixture, as moſt of it falls to the bottom; whiten cloth, though not ſtrongly; and do not weaken it. The oil of vitriol whitens moſt, ſpirit of nitre next, and ſpirit of ſea ſalt the leaſt of the three. They likewiſe make the cloth rough and hard.

Cor. 3. Pearl aſhes extract ſomething from the cloth; ſend up a conſiderable quantity of air-bubbles during the ſolution; make

make it whiter, though with a yellow caſt; but do not ſeem to have any tendency to weaken cloth when kept in the lye. Their power of whitening is ſtronger than that of the mineral acids, but not ſo ſtrong as lime, or a mixture of lime and pearl aſhes. I never could diſcover that they weakened cloth in the leaſt, although it was dried with the lye in it. This is contrary to the general opinion. The reddiſh colour that the lye acquires, and gives to cloth, ariſes from the particular action of alkaline ſalts on the juice of vegetables: for it will appear afterwards, that lint ſteeped in water, affords a pale-coloured tincture; but whenever alkaline ſalts are added to it, the tincture becomes red. The colour, then, is no ſufficient proof of the ſtrength of ſuch tinctures as are drawn with alkaline ſalts.

Dr *Hales* has obſerved, that alkaline ſalts, though they have no effect on the hard calculi formed in the human bladder or kidnies, will diſſolve the ſoft ſtones that are found in the gall-bladder.

Cor.

Cor. 4. *Muſcovy* aſhes have a remarkable power in whitening cloth, but they weaken it much. A bleacher told me, that he once attempted to bleach with theſe aſhes alone, but all his cloth was ſoon eat into holes.

Cor. 5. *Marcoſt* aſhes extract more from the cloth, whiten it more, and weaken it leſs, than *Muſcovy* aſhes do when uſed in the ſame quantity. The cloth in *Exp.* 59. was rather weaker than that in *Exp.* 58.; but there was a half more of the *Marcoſt* than of the *Muſcovy* aſhes. *Caſhub* gives cloth a redder dye than the former, and weakens it as much.

Cor. 6. Stone-lime water whitens more, though it gives the cloth a yellow caſt, weakens more, and extracts more out of the cloth, than any of the former materials. This is ſufficient to deter any perſon from uſing this material by itſelf.

Cor. 7. Oyſter-ſhell lime water enjoys all theſe properties in a much ſtronger degree than the ſtone-lime water; and therefore ought

ought to be deemed the moſt expeditious, but moſt dangerous material for bleaching that is yet known.

Cor. 8. Alkaline ſalts added to lime, diminiſh its power of weakening and corroding cloth; and that in proportion to the quantity of theſe ſalts added to the lime. This compoſition, as it is not ſo dangerous as lime alone, ſo it is not ſo expeditious in whitening. When equal parts of each are uſed, the whitening power is ſtrong, and the weakening power not very conſiderable; ſo that I imagine they might be uſed with ſafety, in the proportion of one part of lime to four of pure alkaline ſalts, to bleach cloth. This fully accounts for an obſervation made by all bleachers, That the bleaching ſalts, when mixed together, operate ſafer and better, than when uſed ſeparately. For the corroſive power of the *Muſcovy*, *Marcoſt*, and *Caſhub* aſhes is corrected by the pearl aſhes, and the whitening quality of the latter is increaſed by that of the former.

There is not a more corroding ſubſtance, with regard to animals, than alkaline ſalts and lime joined together, eſpecially when fuſed in the fire. This is the compoſition of the common cauſtic. But lime, and lime-water alone, preſerve animal ſubſtances in a ſound entire ſtate. It appears then very ſurpriſing, that ſalts and lime ſhould be found ſo little deſtructive to cloth, when lime, or lime-water alone, deſtroy it ſo remarkably. And yet this appears perhaps ſtronger than any other fact, from the whole of the foregoing experiments. So dangerous it is to depend altogether on analogical reaſoning.

THIS corollary is further confirmed, if that is neceſſary, by a paper which, by accident, fell into my hands long before I had made theſe experiments. It lays down a method of bleaching ſafely with lime, as practiſed by the perſon who wrote it. My prejudices were ſo ſtrong againſt the uſe of lime, in any ſhape, before I had tried theſe experiments, that I had not then ſo good an opinion of the method, as I now have. As

it

it contains many judicious obſervations, I ſhall give it as it was delivered me.

Method of bleaching with lime.

" *Firſt*, I ſteep the cloth in warm wa-
" ter for twenty-four hours, then clean it
" in a waſhing mill, of all the dreſſing, or
" ſowen, as the vulgar term it. After-
" wards I buck the cloth with cow-dung
" and water, and bleach it with this for
" three days; then clean it again, and boil
" it with a lye made of *Caſhub* aſhes. A
" pound to each piece of 18 or 20 yards long
" is ſufficient. This I do twice, as no lime
" ought to be given to cloth before it is a
" full third whitened; as it by no means
" advances the whitening of the cloth,
" but, on the contrary, protracts it: for, in-
" ſtead of looſening the oil and dirt in the
" cloth, when brown, it rather fixes them;
" juſt as when fine cloth is bucked with o-
" ver-warm lyes in the firſt buckings.
" Lime is by no means fit for diſcharging
" the oil in the cloth, but for cleaning
" it of the dead part, commonly called

 " *ſprat.*

" *ſprat*. The cloth being cleaned, is
" laid upon a dreeper. It muſt not be
" drier before bucking with lime, other-
" wiſe it will take in more than can be got
" out again before the next application:
" for as I have obſerved already, that lime
" is only fit for diſcharging the dead
" part, bucking thus wet makes it reſt
" on the outſide of the cloth. I take
" a lippy of the fineſt and richeſt powder-
" ed lime that can be got, of the brighteſt
" white colour, as poor lime does more
" hurt than good, to 30 pieces of the a-
" bove lengths; and make a cold lye of it,
" by ſtirrring and pouring water off the
" lime, until all be diſſolved, but the droſs,
" which is thrown away: then I add a little
" ſoap, which makes the lye have the
" neareſt reſemblance to milk that breaks
" in boiling, of any thing I can think of:
" for this ſoap blunts the hotneſs of the
" lime. Then I take the cloth, and dip it
" in the lime-lye, and that moment out a-
" gain, and lay it on a dreeper until it be
" bucked; then put it on the field, watering
" it carefully; for if allowed to dry, it is
" much

"much damaged. This is done always in "the morning; as it cannot be done at "night, in regard of the hot quality of the "lime, which ſoon heats the cloth, and ten- "ders it. If a hot ſunſhine follows, it has "great effect; for lime is juſt like all other "materials for bleaching, that have more or "leſs effect according as the weather is "good or bad. I take it up the ſecond "day after bucking, and give it a little mill- "ing, or hand-bleaching, or bittling, com- "monly called *knocking*; and lay it on the "field again, watering it carefully as before. "The effect is more viſible the ſecond than "the firſt day. As all cloth when limed "ſhould have a great deal of work, other- "wiſe more than half the effect is loſt; and "not only that, but a great deal of labour "and pains is requiſite to take the lime out "of the cloth again; it muſt never be ex- "poſed on the *Sabbath* day, but carefully "kept wet always while uſed in this way. "Thus bucking for three or four times at "moſt, is ſufficient for any cloth, except "that made of flax pulled either over-green, "or which grows in a droughty ſeaſon, or

"perhaps

" perhaps not ſo well heckled as it ſhould be. " This ſort occaſions great trouble and ex- " pence to the bleacher. But the moſt ef- " fectual and expeditious way I ever found " for this kind, was, after boiling, to take " a little of the warm lye, and mix a very " ſmall quantity of lime with it, and draw " the cloth through that as hot as poſſible, " and put it on the field directly, watering " it carefully. This will clean it of the " ſprat ſurpriſingly. Then I boil it with " pearl aſhes, and give it the laſt boil with " ſoap.

" There are innumerable miſtakes in " the uſe of lime committed by the vulgar, " who are ignorant of its quality and effects. " They know only this in general, that it " is a thing which whitens cloth cheap, " and is eaſy purchaſed; therefore they " will uſe it. Some of them begin whiten- " ing of their cloth with it, which I have " already obſerved to be wrong, and given " reaſons for it, and continue it until the " cloth is bleached; give it a boil or " two at moſt, and then waſh it up while

" the

" the groſs body of the lime is in the ſub-
" ſtance of the cloth. This makes limed
" cloth eaſily diſtinguiſhable from unlimed;
" as the former has a yellowiſh colour, and
" is full of a powder. Beſides, as lime is
" of a very hot corroding nature, it muſt
" by degrees weaken the cloth. The bad
" effects of this ſubſtance do not end here.
" When the cloth is put on board, it con-
" tracts a dampneſs, which not only makes
" it yellow, and loſe any thing of colour it
" has, but directly rots it. And although it
" ſhould eſcape this, which it is poſſible it
" may, by a quick and ſpeedy paſſage; yet
" whenever it is put in any warehouſe, it
" will meet with moiſture there, eſpecially
" if the winter-ſeaſon ſhould come on be-
" fore it is diſpoſed, or made uſe of. Theſe
" I take to be the principal reaſons for ſo
" much complaint in bleaching with this
" material."

The whole art and ſafety in uſing the lime, according to this method, depends on the junction of the alkaline ſalts, during the bucking, to the particles of lime which were

were on the ſurface of the cloth. I ſhould rather prefer their junction in the lye; as it may happen, that ſome parts of the cloth which have received the particles of lime, may not, for ſeveral accidents, receive thoſe of the ſalts. That lime is not ſo proper in the firſt buckings, I very much doubt; as it is uſed in the foreign materials, according to the *Dutch* method, from the beginning. The breaking of the lime-water, when ſoap is mixed with it, is owing to the former being a hard water. This will be fully explained in the following ſection. It is not ſurpriſing that cloth bleached with lime alone ſhould, though well dried, contract moiſture, when we conſider the ſtrong attraction or affinity that there is betwixt lime and water.

I have been aſſured, that, in whitening yarn at *Mancheſter*, there is always a fourth part of lime added to the ſalts. I have diſcovered that it is uſed in the ſame way in this country. I know no objection to it, but that of its being againſt law.

Cor. 9. Lime-water, with a grain and a half of pearl ashes added to each ounce, hurts cloth but very little, and whitens very much. This is a mighty cheap composition, and therefore deserves the consideration of bleachers.

Cor. 10. The effects of these different bleaching materials on cloth are increased by heat. They operate stronger when kept in a heat nearly equal to that of the human body, than in the heat of our atmosphere in the summer: they operate still more strongly in the heat of boiling water, provided that heat is brought on by degrees. This is easily accounted for, when we consider, that the intestine motion of fluids is augmented by heat, whereby the impetus or momentum of those solvents become stronger, and consequently their effects sooner produced.

Cor. 11. Those materials that whiten soonest, seem to extract most out of cloth, and to weaken it most speedily; while those that whiten slowly, extract but little from cloth, and therefore do not weaken it. This general rule admits, however, of many exceptions.

Cor. 12. Great plenty of air ariſes during the operation of theſe menſtruums on cloth. This ſhows, that there is ſome ſubſtance, which contains plenty of fixed air, diſſolved, and ſeparated from the cloth. Dr *Hales* obſerved great plenty of air-bubbles ariſing from calculi, while they were diſſolving in ſoap-lyes.

Cor. 13. Acid and alkaline ſalts loſe, in the ſame proportion, as they operate on cloth, their acid and alkaline taſte, and appear to be ſheathed or deſtroyed by a junction with the ſubſtance they extract.

Cor. 14. *Muſcovy* aſhes, having the ſame proportion of pearl aſhes added to them as are uſed in the bleachfield, ſeem to loſe their corroding quality in a great meaſure. The common practice of the bleachfield was ſufficient to have taught this. The

linen-

linen-bag, through which the lye is ſtrained, will ſerve for two years.

Cor. 15. Pure ſea ſalt does not whiten cloth, but opens, thins, and weakens it. Hence kelp aſhes, which contain about a fourth part of ſea ſalt, muſt have the ſame effect. This is one reaſon, among others, why the *Iriſh* cloth is ſo thin and weak, as the kelp aſhes are generally uſed by them in the firſt buckings. Their moſt ſkilful bleachers have laid it entirely aſide, and uſe only the *Caſhub* aſhes. How the kelp aſhes may be freed from the ſea ſalt, I have conſidered in a former ſection.

Cor. 16. Waſhing with warm water and ſoap, and rubbing with the hands, are not capable of taking out all the acid or alkaline ſalts out of cloth that has been ſteeped in them. It is only to be done by alkaline and acid ſalts.

Cor. 17. Cloth boiled in old lye gains conſiderably in weight, inſtead of loſing. Hence it would appear, that old lye is not ſo proper for ſteeping, the deſign of which is to take out the dirt and dreſſing.

Cor. 18. Cloth regularly watered, and expoſed to the influence of the air, loſes conſiderably of its weight, even though it has been well waſhed and rubbed in ſoap and water. This ſhows, that the air, ſun, and winds exhale ſomething, that waſhing and rubbing cannot take out; and therefore that the latter can never ſupply the place of the former, and be attended with the ſame advantage.

Cor. 19. Cloth, during the proceſs of putrefaction, turns blackiſh, throws off a great deal of black matter, and is weakened. Theſe effects muſt depend on the quickneſs and degree of putrefaction. Hence it is long before the putrefaction of plain water weakens cloth. Hence great care muſt be taken, that no corrupted butter milk ſhould be uſed in the bleachfield: A circumſtance too little attended to. The ſame caution muſt be obſerved with regard to the time at which the ſouring proceſs ends;

ends; for immediately to that ſucceeds the proceſs of putrefaction.

Cor. 20. *Caſtile* ſoap appears to be a very weak bleaching material, and not to correct the corroding quality of *Muſcovy* aſhes or lime. It may however be attended with other advantages. I find that it keeps the cloth ſoft. Mr *Chryſtie* ſays, that cloth, when ſoaped, keeps longer moiſt, and is eaſier cleaned from the ſtain of a dirty foot.

Cor. 21. Butter milk ſeems to have ſome gentle tendency to whiten cloth when yet brown. To cloth already white it would ſeem to add ſomewhat, and to recover, in ſome degree, its ſtrength when impaired. By its fermentation the acid particles are diſengaged, and uniting with the abſorbent earth left in the cloth, render it ſoluble in water.

Quær. What effect will the juice of onions, leeks, or celery, have on cloth? They appear by experiment to have a gentle power in diſſolving the ſtone.

Quær.

Quær. What effect will ſhell marl have on cloth?

THESE are all the experiments which I have made with regard to the effects of different bodies on unbleached cloth. Though few, they are ſufficient, I hope, to ſettle the genuine effects of theſe bodies; to teach the bleacher what he is to chuſe, and what to reject; how to balance ſafety and expedition, that his method may not become too expenſive by ſtudying only the former, or too dangerous by purſuing too eagerly the latter; and what is of greateſt importance, by what ſteps the art is to be advanced. But this is not all. The uſe of theſe experiments may be rendered far more extenſive. They teach the varied effects of various bodies, when applied to one another. They increaſe the ſcience of nature, and lead us to its true philoſophy. They heighten our admiration of its great author.

SECT.

S E C T. II.

The cause and effects of hard water, and the methods of softening it.

THERE is no subject so often mentioned, and so little understood, as the cause of hardness in water: there is no subject of greater importance to the bleacher, or indeed to general use; there is no subject, of equal moment, that has been less considered, in an experimental view, than the present; for it lies, so far as I know, yet untouched. These considerations induce me to undertake it. We have hitherto been contented with a showy theory, how well founded, the following experiments will make appear, that sea salt, if not the only, was the most general cause of hardness in water. Even experiments helped to corroborate this opinion; but experiments made with materials not well understood; and therefore deceitful.

THE regular method of proceeding in this inquiry,

inquiry, ſeems this, To try whether we can ſoften hard water, by mixing different materials with it, or treating it in different ways; than to endeavour to harden ſoft water; and, laſtly, from theſe experiments, and from others, to diſcover the true cauſe of the hardneſs in water.

It is neceſſary to define our terms. Water is generally underſtood to be hard, when ſoap, agitated in it with the hand, does not raiſe a froth or lather on the ſurface, nor diſſolves equally through the water, but curdles, or ſeparates into a thicker and thinner part; the former of which mounts to the ſurface, and there remains like a white oil, while the water continues tranſparent below. Hard water has other diſtinguiſhing marks; ſuch as, not ſoftening peaſe that are boiled in it; boiling fiſh better than ſoft water; extracting leſs ſtrength out of malt in brewing; preſerving the colour of greens boiled in it, better than ſoft water; and not taking the dirt out of foul linen ſo well when waſhed in it. Theſe I think too vague and undetermined to be taken as ſtandards for

experiment.

experiment. The curdling of ſoap I ſhall then make my fixed point; on one ſide of which the ſoft waters lie, and on the other the hard. We ſhall call this the *curdling point*. This ſtandard of hard and ſoft water is more certain than any of thoſe commonly known; and has the advantage of being underſtood by every body. Our experiments will furniſh us with a ſubſtance which ſhows the hardneſs of water long before ſoap can diſcover it; but not more certainly. We ſhall make the proper uſe of it afterwards; and follow, at preſent, the common ſtandard of hard and ſoft waters. The hard water uſed in the following experiments, was taken in *July* from a well when it was low.

The water which flows from the pipes diſſolves ſoap eaſily and equally; but this water curdles it directly, and in half a minute the ſoap riſes to the ſurface. In the former water many air-bubbles ariſe on the ſurface, during the agitation, and remain for a long time; but in the latter few are to be ſeen, and thoſe immediately diſappear. In the former *ol. tart. p. d.* makes no lacteſcency or milky colour;

but it does in the latter. The ſoft water was ſpecifically lighter than the hard water; for a piece of glaſs, that weighed in the former 3 dr. 18¾ gr. weighed in the latter half a grain leſs. To diſcover how far beyond the curdling point this hard water was, the following trial was made.

Exp. 84. Three parts of ſoft water and one of hard were mixed, and diſſolved ſoap equally; ſo did two of the former to one of the latter. Equal parts of the ſoft and hard broke the ſoap; but I obſerved through the glaſs, that the ſolution was not quite ſo equal as the former. When the ſoap was mixed with two parts hard to one of ſoft, the ſoap aroſe; but ſeemed to ſeparate with ſome difficulty: and the line of ſeparation was not ſo diſtinct as in the following mixtures, nor the liquor below ſo clear. When it had ſtood half an hour, I mixed the whole together with a ſpoon, and it never afterwards ſeparated. This laſt, then, I muſt look on as the firſt degree of hard water, and the mixture before it as the laſt degree of ſoft water. When three parts of hard were

were added to one of ſoft, the curdling was quick, the line of ſeparation diſtinct, and when mixed together, it again ſeparated. This ſhows how far beyond the curdling point lies the hard water, which I uſed in theſe experiments.

FIRE is generally thought to ſoften hard water. One is naturally led to think ſo, as boiled water has a ſofter taſte than cold water, when made into punch. To aſcertain this point,

Exp. 85. I tried the hard water when it was ſo warm that I could juſt hold my hand in it; but the ſoap curdled as faſt as before. After it had boiled a quarter of an hour, it was ſtill the ſame. There was no alteration, as to this quality, after it had cooled for two hours. Eight *Engliſh* pints were boiled into one; it ſeemed then much harder than before. Boiling, then, appears rather to harden this water, than ſoften it.

IT is the general opinion, that all waters are ſoftened by putrefaction, and that ſtagnation and expoſition to heat are attended with a degree of it. That I might bring this opinion to the teſt of fact,

Exp. 86. *July* 1. I expoſed 4 *Engliſh* pints of this hard water in an earthen veſſel near a conſtant kitchen-fire. *July* 14. Still ſweet and hard. 24. Still the ſame, and continued ſo till it was thrown out, *Nov.* 11. as incapable of corruption. At that time it was reduced to the half; and, inſtead of being ſofter, was twice as hard as at firſt; for it required twice its quantity of ſoft water to make it break ſoap.

When I ſaw that this water had no appearance of becoming putrid, I put, *July* 24. into the ſame quantity of the ſame water, in another pot, a large handful of dung to haſten its putrefaction. The water had a gentle corrupted ſmell for two or three days; but after that, became ſweet, and continued ſo, as likewiſe hard, on the 11th of *November*, when it was thrown out.

That

THAT I might overcome this antiſeptic quality in hard water,

Exp. 87. *Nov.* 11. Into a quantity of this water I put ſome fleſh, and into the ſame quantity I put the ſame quantity of fiſh. *Dec.* 10. Both waters were very putrid. The water in which the fiſh had been, was now ſoft; that with the fleſh was ſtill hard, though a ſmall degree of heat made it break the ſoap too. By another experiment I found, that hard water, putrified by the aſſiſtance of fleſh, became entirely ſoft. Hence we learn, that putrefaction ſoftens hard water; and every tendency towards that proceſs muſt have a proportionate degree of that effect. But hard waters appear to reſiſt that change very powerfully.

IT is generally thought, that hard water filtered through ſand becomes ſoft. I was of the ſame opinion *, and had not truſted to theory alone for it. But being profeſſedly

* Vid. Dunſe Spaw, ſection on water.

engaged

engaged in this purſuit, and having made the experiment more exactly, and carried it farther than what I had done before, I find that this effect of ſand is limited.

Exp. 88. A quantity of ſea ſand was well waſhed with ſoft water, each parcel three times, and then put into two caſks that were ſet above one another. There was a hole in the centre of the bottom of the upper caſk, by which the water was to paſs into the lower; and a hole in the under part of the latter, by which the water was to iſſue through a pen. When the ſand was wet with water, I obſerved it decreaſed conſiderably in its volume. This remarkable property of ſand, which ariſes from a cloſer diſpoſition of its particles by the water as it flows in, is wiſely deſigned, by the author of nature, to anſwer ſeveral valuable ends. That I might waſh out all the ſalts or ſoluble parts from the ſand, ſoft water was filtered through it. The water came off hard for two days; but after that became ſoft. The hard water was then paſſed through the ſand, and it came off entirely ſoft; nay

more

more ſo than the town-well water; as it ſeemed to diſſolve ſoap better, when equal parts of it and hard water were mixed, than the town-well water had done in the ſame proportion. It appeared ſofter from the following trial. Three parts of the filtered hard water were mixed with one part hard water; the town-well water was mixed in the ſame proportion. *Ol. tart. p. d.* produced a lacteſcency in the latter, but not in the former: but when there were two parts of hard water to three of filtered, a lacteſcency juſt began to appear. But how cautious ought we to be in drawing general concluſions from the apparent ſucceſs of an experiment! The water, running through a quill in a conſtant ſtream, continued ſoft for twenty-four hours; but after that it turned hard, and remained ſo.

THIS is eaſily accounted for. The ſubſtance, whatever it is, which makes water hard, finds great difficulty in paſſing through the interſtices of the ſand, but is not altogether ſtopped. Hence, by degrees, it is waſhed down by the water, and lies ready

to

to impregnate the ſoft water which is iſſuing through the quill, while its place is ſupplied by that immediately above it; and ſo on in a continual ſucceſſion. Thus the water muſt after a certain time become hard. From this experiment we may conclude, that ſoft ſprings at leaſt are not ſupplied by the ſea, as ſea-water is hard.

THIS method of filtration may ſtill be very proper to free impure waters of the filth they contain, or of their earthy and oleaginous particles, and clarify them. The water before it was filtered, was not only hard, but had a bad taſte. Its taſte after filtration was quite altered: it was nauſeous before, but had a ſaline ſweetneſs after.

I have heard, that great quantities of chalk thrown into wells of hard water made it ſoft. With this view I tried the following experiment.

Exp. 89. Powder of chalk, mixed with hard water, did not ſoften it. When boiled for a quarter of an hour in hard water, and

and allowed to subside, the clear liquor was no softer than before. It does not therefore soften water, by any change that it makes on the water from an addition of its substance: but if it has that effect, it must act as a filter. This appears to be its method of acting: for hard water filtered through a height of chalk of two inches, came off so soft, that it broke soap; but *ol. tart. p. d.* produced a lactescency, in three parts of it mixed with one part hard water. The water filtered through the chalk so slowly, that I should be afraid of its not allowing the water to pass in any quantity, if the spring be in the bottom of the well. This was the case, as I am told, in a well where this experiment had been tried; for, afterwards, in dry weather it was always so low, that they could get no water out of it.

Exp. 90. Some hard water was clarified, by having the white of an egg beat up with it, and afterwards boiled. The soap broke pretty well at first in it; but, on standing ſome ſeconds, it curdled, and roſe to the ſurface.

LIME was tried to ſoften hard water, and not without ſome hopes of ſucceſs: for as it is thought a great corrector of the muriatic acrimony in the blood, it might have the ſame effect on the muriatic ſalts, the ſuppoſed cauſe of the hardneſs of water.

Exp. 91. Lime was mixed with hard water, but it was not ſoftened by being made into lime-water. The ſame lime-water ſtood till the calcarious particles were all evaporated, but ſtill the water preſerved its natural hardneſs. We ſhall ſee preſently that the real effect of lime is very different from the imagined one.

Exp. 92. It is generally thought, that fern ſoftens water; and it is often uſed with that deſign: but infuſing ſome of that vegetable in warm hard water, and letting it ſtand all night, I could not diſcover any ſuch effect. The ſalts in it, though they do not ſoften the water, may perhaps quicken the effect of of water, when it is to operate as a menstruum, to loosen the oils of vegetables: for it is in the steeping of lint that fern is used.

Let us try what experiments made on no previous theory will produce.

Exp. 93. The extract of bark, of gentian, and of centaury, appeared, at my first trial, to have a power of softening hard water; but, on repeating the experiment, I found, that the dark colour of the solutions, or the mixture of some alkaline salts with these extracts, which sometimes happens, had misled me. Nor did I succeed better in softening hard water with the extract of wormwood, of black hellebore, of chamemile, or of logwood; with rhubarb, Bohea tea, lintseed, oak bark, gum Arabic, or gum ammoniac.

Exp. 94. A solution was made of 2 scrup. of blue pearl ashes in 2 oz. of soft water. Sixty drops of this solution, mixed with a spoonful of hard water, dissolved soap without curdling. A hundred drops of a solution, that contained juſt 5 gr. of blue pearl aſhes, made four ſpoonfuls of hard water ſoft; but the ſoap curdled on the addition of another ſpoonful. We have then found a ſoftener of hard water where it was not expected. This experiment led me to try the following.

Exp. 95. Twenty drops of the ſpirit of harts-horn ſoftened two ſpoonfuls of hard water. The ſame number of drops, mixed with the ſame quantity of hard water, and allowed to ſtand for two or three days till the ſmell of the ſpirit was gone, broke ſoap as well as with the recent addition. That I might find out the preciſe quantity of dry volatile ſalt, I diſſolved 2 gr. in half a ſpoonful of hard water, which broke ſoap well; but when I added another half-ſpoonful, it was with ſome difficulty that it broke ſoap: but after it had done it, there was no ſeparation. Thus we have found two ſubſtances, the fixed and volatile ſalts, which have a remarkable effect in ſoftening hard waters. How far theſe may be applied with ſafety to the common uſes of life, we ſhall afterwards conſider.

Let us next endeavour to diſcover what ſubſtances make water hard. I could not procure diſtilled or rain water in quantity enough to ſerve me in all the following experiments; but the moſt important were performed with the latter. We ſhall begin with the mineral ſubſtances.

Exp. 96. A large key was infuſed in ſoft water for a day: it made the water yellow, and gave it a ſtrong chalybeate taſte, but did not harden it. Neither did a red-hot iron quenched ſeveral times in ſoft water. Copper infuſed in ſoft water for two days, gave it a mineral taſte; but did not change it into hard water.

Sea ſalt is commonly thought, if not the only, at leaſt the moſt general cauſe of the hardneſs in water. It was natural to think ſo, when we found, that common ſea ſalt curdled ſoap diſſolved in water, and conſidered how general an ingredient it is in all waters.

waters. But the following experiments will ſhow us, that this is not the effect of ſea ſalt, but of the impurities mixed with it. The ſea ſalt, which I uſed, is a particular kind that is only made on *Sunday*; and therefore called *Sunday-ſalt*, or great ſalt, from the largeneſs of its grains. It cryſtalliſes at a time when the fire is low, and the ſea water not altogether evaporated, as it is in the common way of making ſalt. It contains leſs of the bittern than the common ſea ſalt, and has therefore a particular ſweetneſs. It is the moſt proper for the table and for experiments.

Exp. 97. A grain of pure ſea ſalt was diſſolved in 4 ſpoonfuls of rain-water. This ſolution diſſolved ſoap well, and did not turn lacteſcent with *ol. tart. p. d.* Some drops of a ſolution of quickſilver in *aq. fortis* made a great lacteſcency in it; this lacteſcency was juſt perceptible when the ſolution of the ſea ſalt was diluted with ſixteen times its quantity of water. This ſolution of quickſilver, then, does not diſcover hard waters; it only diſcovers ſea ſalt in water;

ter; and that when in a very ſmall proportion, 1 gr. in 3 *Engliſh* pints of water.

Exp. 98. A ſpoonful of rain-water, with 5 gr. of pure ſea ſalt diſſolved in it, continued ſoft. With 6 gr. there appeared a little curdling, but a little more agitation diſſolved the ſoap. This curdling ſeems to be owing to ſome remainder of the bittern; for 2 gr. of common ſea ſalt made water as hard as theſe 6 gr. had done. The bittern has this quality ſo ſtrong, that a fourth part of a grain of the bittern ſalt hardens a ſpoonful of rain-water. The ſpirit of ſea ſalt ſaturated with an alkaline ſalt, does not harden water. The proof ſtill becomes ſtronger, when a ſmall lacteſcency appears on dropping *ol. tart. p. d.* into a ſolution of 5 gr. of pure ſea ſalt in a ſpoonful of rain-water. From theſe facts it appears, that pure ſea ſalt has no hardening quality, and that the bittern has it in a very ſtrong degree. The hardneſs of waters can never be owing to the former ſalt, as the taſte can diſcover a ſmaller admixture of it than what would be

neceſſary

neceſſary to have that effect, if it ever has any ſuch.

THUS pure and impure ſea ſalts appear, by experiment, to have very different effects on bodies. I am afraid this has not been ſufficiently attended to; and the effects of the bittern have often, unjuſtly, been attributed to ſea ſalt. I have diſcovered, ſince I made the preceding experiment, that *Lemery* has long ago made the proper diſtinction betwixt theſe ſalts *.

THE common *Epſom* ſalt, ſold in the ſhops, is the bittern or ſecond kind of ſalt in ſea water.

Exp. 99. Five grains of *Epſom* ſalt hardened 2 ſpoonfuls of ſoft water ſo much, that it required to be diluted in 16 ſpoonfuls, before it began to break ſoap. A great lacteſcency happened betwixt this ſolution and *ol. tart. p. d.*

Exp. 100. Alum renders ſoft water very

* *Cours de chymie, p.* 307.

hard;

hard; so that 5 gr. required 20 spoonfuls of soft water before it would break soap. *Ol. tart. p. d.* made a lactescency.

Exp. 101. Salt of steel hardens water. I was obliged to dilute 10 gr. in 45 spoonfuls of soft water to make it break soap. Every one knows, that alkaline salts render a solution of this salt turbid and green.

Exp. 102. Blue vitriol or salt of copper hardens water so much, that 5 gr. required to be diluted in 35 spoonfuls of soft water to make it break soap. Alkaline salts turn a solution of this turbid and blue.

Exp. 103. Vitriolated tartar got from the apothecary's shop hardened water; but finding that it had a strong acid taste, I made some, by dropping 40 drops of spirit of vitriol into a solution of salt of tartar. When the saturation was fully completed, I put the whole into two spoonfuls of soft water, and it dissolved soap very well. No lactescency.

Exp. 104. Five grains of the ſugar of lead hardened water. When diluted in 24 ſpoonfuls, it began to diſſolve ſoap. The alkaline ſolution made a lacteſcency in it.

Exp. 105. Crude ammoniac ſalt, borax, ſal prunel, ſal polychreſt, gum ammoniac, chamemile flowers, oak bark, Peruvian bark, did not harden water. Nor did oil of tartar produce a lacteſcency in their ſolutions.

Exp. 106. Five grains of cream of tartar hardened ſoft water; but when diluted in ſix ſpoonfuls, it diſſolved ſoap. No lacteſcency.

Exp. 107. Five grains of ſalt of amber made water ſo hard, that I was obliged to dilute it with 50 ſpoonfuls before it would break ſoap. No lacteſcency.

Exp. 108. Twelve drops of ſpirit of vitriol required eight ſpoonfuls before it would diſſolve ſoap. One drop of oil of vitriol required to be diluted in ſix ſpoonfuls, the

ſame

fame quantity of fpirit of fea falt in five fpoonfuls, the fame of nitre in three fpoonfuls of foft water, before foap could be equally diffolved. A tea-fpoonful of vinegar required eight large fpoonfuls of foft water to make it break foap. The alkaline folution raifes an effervefcence, though it does not make a lactefcency with thefe acids.

Exp. 109. Some powder of chalk was well mixed with cold foft water: it was poured off after the chalk fettled, and diffolved foap. Soft water boiled with chalk for half an hour, was not hardened by it. Some clay wrought for fome time in water, and allowed to fubfide, did not harden it. Lime renders water remarkably hard.

Exp. 110. Lime-water that was made with foft water, and had ftood for three or four days over a great quantity of lime, which had before afforded fome pints of lime-water, curdled foap at once, and became milky with the alkaline folution. One fpoonful of this lime-water required fix fpoonfuls of foft water before it broke foap.

Ten ounces of lime-water was boiled into two, but it diſſolved ſoap no better than before. The ſame lime-water, when it had become vapid with ſtanding, broke ſoap as well as ſoft water. The hardneſs of lime-water appears plainly to be owing to the ſoluble parts of the lime; and the more water contains of theſe, it muſt be the harder. We cannot know from this the real quantity of theſe particles contained in the water; but we may know the proportionate quantity; and of courſe the comparative ſtrength of different lime-waters. Let us, then, try to determine, by this teſt, an intereſting queſtion, Whether double or triple lime-water is ſtronger than ſingle?

Exp. 111. I made ſome lime-water; in half an hour I poured moſt of that ſingle lime-water upon freſh lime; about the ſame time after I poured moſt of that double lime-water upon freſh quick-lime; and ſo made a triple lime-water. When they had all ſtood about two hours, a ſpoonful of the ſingle lime-water required to be diluted with 9 ſpoonfuls of ſoft water, before it would

would break ſoap; the double required 12, and the triple 15. The times and force of agitation were, as near as I could make them, the ſame. I poured the triple lime-water again upon quick-lime. The other lime-waters were poured from the lime into open glaſſes. An hour and an half afterwards the ſingle lime-water required 9 ſpoonfuls, the double 11, the triple 13, and the quadruple 17. This laſt experiment was made at twelve at night. Next morning the whole four lime-waters, having ſtood all night in open glaſſes, required but 9 ſpoonfuls, although the quadruple lime-water had ſtood over its lime all the night. This experiment agrees exactly with what I had formerly diſcovered by weighing their ſpecific gravities. A piece of glaſs weighed 2 dr. 23 gr. in town-well water; in ſingle ſtone-lime water it loſt a grain, and in triple a quarter of a grain more. This ſhowed, the ſpecific gravity of the triple lime-water was greater than that of the ſingle, by a fourth of the difference betwixt the laſt and plain water. The lime-waters in this laſt experiment had ſtood for

two

two hours, till they were entirely clear.

I repeated the former experiment again, and I ſtrained the waters, after they had ſtood an hour, through brown paper. The ſingle lime-water required 8 ſpoonfuls of ſoft water before it broke ſoap, the double 9, and the triple 11. I was reſolved to ſee how far it would go, and made a quadruple; but, finding it took no more than the laſt, I deſiſted.

That I might diſcover how long theſe different lime-waters would preſerve a difference in ſtrength, if kept in cloſe bottles,

Exp. 112. I made ſingle, double, and triple lime-waters, ſtirred them frequently for four hours, and then ſtrained them. The ſingle required 15 ſpoonfuls of ſoft water, the double 18, and the triple 20, before they broke ſoap. They were bottled, corked, and waxed over. After they had ſtood 10 days, they required the ſame quantity as before to ſoften them. When kept ſome days longer, the ſingle was ſtill of the

the ſame ſtrength, but the triple required only 18 ſpoonfuls of ſoft water.

As it may be objected to theſe experiments, That the water had not ſtood a ſufficient time over the lime, nor had they been frequently mixed together,

Exp. 113. I made two different quantities of lime-waters, with two parcels of the ſame quick-lime. I tried one of the lime-waters in the above-mentioned way, after it had ſtood without ſtirring for two hours. The other ſtood over the lime twenty-four hours, and was frequently ſtirred. They were equally hard, and therefore equally ſtrong. Lime-water then made with unſlaked lime, need ſtand no longer than it is clear.

The concluſion, then, from theſe experiments, is, that lime-waters made with different lime, differ very much from one another; that double lime-water is ſtronger than ſingle, and triple than double; and that they retain their different ſtrengths, if

kept

kept from the influence of the external air; but if expoſed to it, in open veſſels, in a few hours become of equal ſtrength.

To try what effect alkaline ſalts had as to the ſoftening of lime-water,

Exp. 114. I poured on quick-lime ſome water, in which the fourth part, in proportion to the lime, of blue pearl aſhes had been diſſolved. The water had a ſharp pungent taſte, and ſeemed to be about the hardneſs of the hard water, which, though hard, is much ſofter than lime-water. The ſoftening power of the alkaline ſalts, appears yet better from the following experiment. One ounce of potaſhes diſſolved in two gills of water, and poured on an ounce of quick-lime, produced a very cauſtic liquor, which broke ſoap, but not ſpeedily. Lime-water is ſoftened by an addition of alkaline ſalts. From this experiment we may ſee the reaſon, why the ſoap mixed with the lye, which is a compoſition of lime and alkaline ſalts, is not curdled.

A table of the comparative power of bodies with regard to ſoftening and hardening of water.

Comparative ſoftening powers.

Filtration through ſand ſoftens in proportion to the length of its courſe.

Putrefaction ſoftens in proportion to its degree.

Volatile ſalt of hartſhorn ——	1
Fixed alkaline ſalts, though not of the ſtrongeſt kind —— ——	2

Comparative hardening powers.

Epſom ſalt —— ——	3
Alum —— —— ——	4
Salt of ſteel —— ——	4½
Blue vitriol —— ——	7
Sugar of lead —— ——	5
Cream of tartar —— ——	1½
Salt of amber —— ——	10
Oil of vitriol —— ——	18
Spirit of ſea ſalt —— ——	15
Spirit of nitre —— ——	9
The ſoluble part of lime ——	45

In computing the hardening power of theſe acid ſpirits, I have allowed 3 drops to be equal to a grain; which may ſerve very well in a general way of computation. But when we conſider, that there is but a part of theſe ſpirits real acid, and that thoſe which I uſed had been negligently kept, we ſhall ſee reaſon for attributing a very ſtrong hardening power to the real acid ſalts of theſe liquors. By the trials which I have made, there appears to be but 1 gr. of the ſoluble part of lime in 5 oz. of lime-water, which I reckon equal to 8 ſpoonfuls; and one ſpoonful was found to require 6 ſpoonfuls of ſoft water to make it break ſoap.

It muſt be obſerved, that all theſe artificial hard waters, except thoſe made ſo with acids, were rendered turbid or lacteſcent with alkaline ſalts. This will be found a general rule, That where-ever ſoap is curdled, alkaline ſalts produce a change in the colour and purity of the water; becauſe both effects depend on the ſame cauſe. Hence ariſes a new ſtandard to help us to judge of the degree of hardneſs in waters. Let

us

us inquire at what time this change of colour arifes; it may, perhaps, difcover a lefs degree of hardnefs in water than foap does.

Exp. 115. A mixture was made of equal parts of hard and foft water. This we found before not capable of curdling foap, and, therefore, called it the laft degree of foft water. This foft water, on dropping fome of the folution of pearl afhes into it, turned as white as the hard water did with the fame folution. When two parts of foft water and one of hard were mixed, a lactefcency arofe with the folution, but weaker than in the laft. When three parts of foft were mixed with one of hard, a very difcernible alteration of colour ftill happened. Thus we fee, alkaline falts difcover a much lefs degree of hardnefs in water, than what foap does. Let us therefore call this degree of hardnefs in waters, whereby they are made to change their colour with alkaline falts, the *lactefcent point*.

We are now on a better footing than what we were when we fet out. We have gained two fixed points in hard waters, that will allow of comparifon. We may now divide all waters, with regard to this quality of hardnefs, into three forts. The firft are thofe which neither change with alkaline falts, nor curdle foap; the fecond, thofe which lofe their tranfparency with thefe falts, but in which foap is not curdled; the third fort are thofe where both effects happen. The firft clafs are the fofteft of all waters, and the fitteft for moft ufes in life; the fecond clafs, at leaft the firft degrees of that clafs, may do tolerably well in the common houfehold-affairs, though not in the bleachfield; but the third fort I condemn as hurtful, and improper in almoft all cafes. The water which iffues from the pipes of *Edinburgh* wells, is in the firft clafs: for it not only breaks foap well, and retains its tranfparency when falt of tartar is mixed with it; but likewife fhows no lactefcency, when a folution of quickfilver in aqua fortis is dropped in it. By this laft we difcover, that if it contains any fea falt, it muft be in a lefs proportion than one grain to three

Englifh

English pints; too inconfiderable a quantity to be taken notice of.

The foregoing obfervation leads us likewife to another very material conclufion; which is, that the curdling of the foap is brought about by the alkaline falts, and not the oil: which two bodies, with a little lime and fea falt, make up the compofition of hard foap. The fea falt has not that effect, as we proved before; and the lime is in fuch a fmall proportion, and mixed with alkaline falts, which we juft now found foftened it, that it cannot be the caufe of the curdling of foap. We have found, that neither natural nor artificial waters ever curdle foap, without having their compofition altered, or vifibly affected by alkaline falts: it therefore follows, that the alkaline part of the foap is the part on which thefe hard waters work. Accounting for the lactefcency with falt of tartar, is accounting then for the operation of foap. It is no wonder that hard waters produce their effect fomewhat later on foap, as it is defended by the oil from their operation longer than

than the naked ſalts. As ſoap is a more compounded body than the ſalts, the circumſtances reſulting from a mixture of hard water with each muſt be very different.

We have diſcovered, in theſe experiments, three different cauſes of hard water; quick-lime, acids, and neutral ſalts. This property in lime ſhall be examined by itſelf. Acid ſalts, ſuch as the oil and ſpirit of vitriol, the ſpirit of ſea ſalt, and that of nitre, vinegar, Cream of tartar, and ſalt of amber, hardened water remarkably. Why they ſhould do ſo, is eaſily explained. The alkaline ſalts having a ſtronger tendency to the acid than to oil, quit the latter, and adhere to the former. Hence the artificial compoſition of ſoap is deſtroyed, and the oily part, ſeparated from the alkaline, floats like clouds, and at laſt, by its ſpecific lightneſs, riſes to the ſurface. The ſtronger the acid is, every thing elſe equal, the harder muſt it make the water. Hence the mineral acids, conſidering the great proportion of real acid in them, have the ſtrongeſt effects: but theſe can ſeldom or never im-

pregnate

pregnate natural waters, becaufe abforbent particles are found almoft every where; which would directly join the acids, and reduce them to neutral falts. In fact no acid water has yet been difcovered. This leads us to confider thefe neutral falts as the general caufe of hardnefs in water.

When I look back on thefe experiments, I cannot but obferve one remarkable fact; which is, that none of the more perfect neutral falts, compounded of an acid and alkaline bafe, render water hard; but that all the imperfect falts, compounded of an acid and abforbent earth, or a metal, have this effect on water. *Epfom* and alum falts have an abforbent earth for a bafe; falt of fteel, fugar of lead, and falt of copper, a metallic one. It is a fact known to all chymifts, that when alkaline falts are poured on a folution of the imperfect falts, the acid quits the abforbent earth or metal, and joins the falts; becaufe the power of attraction betwixt the acid and falts is ftronger than betwixt the acid and earth or metal. But when thefe alkaline falts are added to the folution

lution of the more perfect ſalts, no change can happen; becauſe the alkaline ſalts, to which they are already united, attract the acid as ſtrongly as thoſe that are now added. It is the ſame thing then with reſpect to the alkaline ſalts, whether the acid is or is not joined to a metal or abſorbent earth, ſince it ſo eaſily leaves them. But the effects which follow will be different: for, in the former caſe, the liquor muſt loſe its tranſparency, at leaſt for ſome time, on account of the deſerted particles which float in the liquor; but in the latter no ſuch effect can happen, and the liquor muſt continue limpid.

Hence ariſes already a great preſumption, that theſe imperfect ſalts are the common cauſe of the hardneſs in waters, ſince the appearances in both caſes correſpond ſo exactly: for a curdling of ſoap, a lacteſcency, and precipitation, are obſerved in both natural and artificial hard waters. But it muſt ſeldom happen, that the hardneſs of waters is owing to a neutral ſalt, compoſed of an acid and a metallic baſe; conſidering

ing how much oftener the acid muſt be joined to an abſorbent earth. The former does ſometimes happen: for the *Hartfield* water is very hard; and experiments ſhow, that it contains a ſalt of ſteel, and no other. When this is the caſe, the water becomes a mineral water, and will ſoon diſcover itſelf by its mineral effects. In all hard waters, then, excepting the mineral, we may preſume, that there is an imperfect neutral ſalt.

THIS cauſe of hardneſs in waters accounts for the power which alkaline fixed and volatile ſalts have of ſoftening theſe hard waters. Theſe two bodies unite themſelves with the acid, and throw off the abſorbent earth: the fixed ſalts conſtitute with the acid a perfect ſalt; which ſpecies of ſalts, as we already diſcovered, has no power of hardening water; and therefore the water becomes ſoft. The volatile alkaline uniting with the acid conſtitutes an ammoniacal ſalt, or one like it; which we found likewiſe not to harden water; and therefore the hard water becomes ſoft. The water is rendered by that change on the ſalts more healthful; which we were not ſure of when the fact was firſt diſcovered.

LET us try how far experiment will ſupport this theory of hard waters: for I can allow it to be as yet nothing but a theory, though a plauſible one; ſince it ariſes only from a ſimilitude of effects betwixt natural and artificial hard waters. If this theory be true, we ſhall be able to exhibit to the eye theſe hardening ſalts, or at leaſt ſome part of them; by which we may diſcover, that the other part has been once preſent. Let us ſee what evaporation will give us.

Exp. 116. Four *Engliſh* pints of this hard water were evaporated to drineſs, and left 26 gr. of a brown powder, which had a pungent ſaline taſte, and liquified in the air. This powder efferveſced with both vegetable and mineral acids; but it efferveſced likewiſe with a ſolution of alkaline ſalts. It muſt therefore be a compoſition of both acid and alkaline ſalts, or abſorbent earths; the latter of which ſeem to prevail, as the powder

powder turned the ſyrup of violets green. Brown paper dipped in a ſolution of it, and dried, burnt like a nitrous match. Six grains and a half of the powder diſſolved in a pint of ſoft water, made it ſo hard, that it would ſcarcely diſſolve ſoap. In this reſiduum, then, we have diſcovered the hardening cauſe; but it appears, that about the half of it has been diſpelled by the evaporation. It is probable, that this volatile part is an acid, as the reſiduum ſeems to partake moſt of a contrary nature.

LET us ſee whether we cannot make this acid more fixed and more viſible, by joining it to an alkaline baſe.

Exp. 117. Into four and a half gills of hard water, was dropped *ol. tart. p. d.* as long as any lacteſcency was made by it. During the addition of the alkaline ſalt, I obſerved through the glaſs a very great inteſtine motion in the liquor: ſome air-bubbles, though but very few, aroſe; and the clouds diſperſed themſelves through the whole with a conſiderable motion. But no ſuch effect happened when I dropped the ſame ſolution into ſoft water. Here then is a plain and diſtinct inteſtine motion or effervefcence. The liquor, having ſtood all night, appeared tranſparent in the morning, and the bottom of the glaſs was covered with a whitiſh powder. The water now broke ſoap. When the whole was ſhaked, it turned white; which ſhows the milky colour is owing to this powder. The liquor was ſtrained through brown paper, and I had five grains and a half of white powder. To be ſure that this precipitation did not ever happen in ſoft waters, and that it was no part of the alkaline ſalt, I dropped the ſame quantity of *ol. tart. p. d.* into the ſame quantity of ſoft water; but no precipitation followed. This powder, when mixed with ſoft water, did not harden it; when kept in a ſtrong kitchen-fire for two hours, it was reduced to good quick-lime.

THAT I might diſcover the contents of the hard water, after the addition of alkaline ſalts, *Exp.* 118. Three chopins of hard water were treated in the ſame way, and evaporated to 2 oz. of a red liquor. The firſt ſalt that ſeparated from the liquor weighed 15 gr. It turned ſyrup of violets green, and effervеſced with ſpirit of vitriol; marks of its being alkaline. More alkaline ſalts had been added than what were neceſſary. The next cryſtalliſation afforded me a ſcruple of a ſalt, which, though it ſeemed to be of an alkaline caſt, approached much nearer to the neutral ſtate than the former, gave ſtrong marks of a nitrous ſalt, and afforded me great hopes from the next cryſtalliſation. It ſucceeded accordingly. In a night's time I had half a drachm of fine white cryſtals, ſome of them an half-inch in length, and exactly like the regular cryſtals of nitre. They had a bitter cooling taſte; when joined to oil of vitriol, emitted ſtrong acid fumes, and corroded ſilver; when vinegar was poured in them, a few air-bubbles aroſe: but theſe ſeemed plainly to be owing to the alkaline liquor round them; for the cryſtals lay for ſome time, after the inteſtine motion ceaſed, undiſſolved at the

the bottom of the glaſs: when brown paper was dipped in a ſolution of them, it burnt, and ſparkled like the ſame dipped in a ſolution of ſaltpetre. Theſe characteriſtical marks, with its effects of turning fleſh red when boiled in the water, are ſufficient to prove it to be a real ſaltpetre; for theſe are the properties of that ſalt, and belong to no other. The liquor remaining was of a dark colour, and taſted like a ſolution of ſea ſalt.

The earth in this hard water we demonſtrated before to be of the calcarious kind, and convertible into lime. We have at preſent demonſtrated the acid of this hard water to be that of nitre. The chymiſts deny that ſuch an acid exiſts in nature, and affirm, that it is made from the vitriolic and an inflammable principle conjoined: but here we have found it preſent, and have helped to volatilize it. *Hoffman* denies the exiſtence of nitrous waters, and ſays, that an inflammable foſſil nitre is no where to be found *. Here, indeed, the nitre was in

* De element. aq. mineral. *&c.* par. 39.

an imperfect ſtate, but ſtill inflammable. There is great probability, that a real nitre may ſometimes exiſt in the bowels of the earth, ſince the alkaline baſe often appears in waters. The experiments performed on mineral waters at *Paris* before the Royal academy of ſciences, demonſtrate clearly the exiſtence of a nitrous ſalt *.

Since this acid ſeems of ſo volatile a nature, let us try if hard water diſtilled gives any ſign of containing an acid.

Exp. 119. I diſtilled ſome hard water. The diſtilled water ſhowed no effervefcence with alkaline ſalts, but turned the ſyrup of violets into a light red. Common ſoft water had no ſuch effect. Here, then, we diſcover an aceſcent quality in the ſteams of hard water, that can riſe only from an acid exiſting in that water; and as the water gives no marks of acidity, we muſt conclude, that, by adhering to an abſorbent baſe, it is converted to a neutral ſalt.

* Vid. Du Clos.

There

THERE cannot be a ſtronger proof that waters owe their hardneſs to ſuch a ſalt, than to ſhow that ſimilar artificial compoſitions have this effect. Such ſalts as theſe muſt be continually produced by nature; as an acid and different abſorbent earths are almoſt every where to be found.

Exp. 120. Four grains of the earthy reſiduum of white pearl aſhes were ſaturated with the ſpirit of vitriol, and half an ounce of water added. Two parts of this ſaline liquor added to three of the rain-water, would not break ſoap.

Exp. 121. The ſame quantity of chalk was managed the ſame way. Two parts of this to three of rain-water made the ſoap riſe to the ſurface.

Exp. 122. Six drops of ſpirit of nitre, ſaturated with chalk, made ſoft water ſo hard, that it required 60 ſpoonfuls before it would break ſoap.

Exp. 123. The ſame quantity of ſpirit of

ſea

ſea ſalt ſaturated the ſame way, required 80 ſpoonfuls.

Exp. 124. The powder which was precipitated by *ol. tart. p. d.* from three *Engliſh* pints of hard water, being ſaturated with oil of vitriol, made the ſame quantity of ſoft water nearly as hard as what the former had been; for equal parts of this artificial hard water mixed with ſoft, diſſolved ſoap, though with ſome difficulty. The quantity of acid added was 66 drops. There was a great part of this earthy ſubſtance, which the acid could not diſſolve.

These different experiments ſeem to have clearly made out, that the hardneſs in this water is owing to an imperfect ſalt, compounded of the nitrous acid and an abſorbent baſe. It is probable, that moſt waters, excepting the mineral, owe their hardneſs to the ſame cauſe; eſpecially when we conſider that it is obſerved of them all, that they give fleſh boiled in them a red colour. I have examined many different hard waters in different parts of the country, and have always diſcovered the acid to be nitrous, but the baſe only abſorbent, and never calcarious but in the foregoing. Thus we ſee the very ingenious Dr *Stephen Hales* has come near the true cauſe, when he ſays, "That the hardneſs of many waters, and "their curdling and coagulating of ſoap, may "be, in a good meaſure, owing to the tar-"tarine quality with which they are impreg-"nated." By the tartar of waters, the Doctor, I ſuppoſe, means that ſtony part which is depoſited on the inſide of veſſels. This is, indeed, one part of the compoſition of theſe hardening particles: but this alone we found to have no ſuch effect; it is to the acid, and theſe abſorbent earthy particles, compounded into a neutral ſalt, that we have, by experiment, diſcovered this hardneſs to be owing.

Having now examined the effects of alkaline ſalts on natural hard waters, and, by that means, made a diſcovery of their nature, let us examine the effects of theſe ſalts on lime-water; for that, perhaps, may give us ſome light into the nature of lime.

Exp.

Exp. 125. Into 6 gills of lime-water, ſtrained from the cruſts, I poured a ſolution of alkaline ſalt, till no more lacteſcency appeared. The quantity of dry alkaline ſalt required, was 8 gr. During the addition of the ſolution, there appeared a great inteſtine motion, ſuch as happened in the hard water; the milky clouds moved ſwiftly through the fluid; but I perceived no air-bubbles. It is not, however, in the appearance of air-bubbles, but in the inteſtine motion, that an efferveſcence conſiſts. The lacteſcent mixture, having ſtood all night, was clear next morning, and had depoſited a white powder. The whole being ſhaked together, was ſtrained through brown paper, and left an impalpable powder, weighing 4 gr. when dried. The remaining liquor did not efferveſce with acids; and when evaporated, left 11 gr. of a light brown powder.

The former powder did not liquify in the air, nor diſſolve in the mouth like a ſaline ſubſtance. It taſted as if a little ſea ſalt had been mixed with it. It efferveſced ſtrongly with ſpirit of vitriol; and emitted a ſharp acrid ſmell, when oil of vitriol was mixed with it. Being calcined, and mixed with water, it afforded a good lime-water.

The latter powder had a pungent ſaline taſte, turned moiſt by keeping, was not altogether diſſolvable in water, did not afford a lime-water before calcination, and effervesced ſtrongly with vinegar. Three grains of the powder mixed with 1½ oz. of water, made it turbid, and the powder fell directly to the bottom. Some of the water, when ſtrained, effervesced with ſpirit of vitriol. This ſhows, that part of the powder is diſſolvable. With the remaining unſtrained liquor, ſpirit of vitriol made a ſtrong effervescence; there remained half a grain of powder that was undiſſolvable by the ſpirit. Some of the powder being calcined for two hours, I got an acrid pungent ſubſtance, which taſted exactly like a lye of ſalts and lime, and had the ſame taſte when diſſolved in water.

Exp. 126. I tried this experiment again, to to be aſſured of the facts. The ſame quantity of ſtrained lime-water was uſed, and the ſame quantity of the ſame ſolution. The reſiduum left in the paper weighed 6 gr. and that got by evaporation from the liquor weighed 10 gr. The latter was now ſo cauſtic, that it bliſtered the tongue on touching it; was almoſt indiſſolvable in water; and had the taſte of the cauſtic liquor drawn from lime and ſalts. The former, when calcined, taſted juſt like quick-lime; made a hiſſing noiſe when water was poured on it; and gave good lime-water.

It is difficult to account for theſe phenomena: we ſhall, however, make ſome attempt towards it, and carry, when it is poſſible, experiment along with us.

It is ſufficiently made out by Dr *Alſton*'s accurate experiments, that quick-lime conſiſts of a diſſolvable and an undiſſolvable part. The former appears to be about the third part of the whole. The latter is reducible, by fire, into the former; and therefore we ſhall treat only of the diſſol-

vable

vable part. There are many diſputes concerning its nature. That it ſhould be ſo, is not at all ſurpriſing, conſidering how late chymiſts were in examining this ſubſtance, and how few experiments have yet been tried with regard to it.

The firſt diſpute is, whether it ought to be called a ſalt or not? This ſeems only to concern words. If the definition of a ſalt had been firſt given, I imagine this diſpute would ſoon have been determined. If a ſalt be a ſubſtance which has a pungent taſte, and is diſſolvable in water; and I know no other definition but this, that can ſuit all ſalts; ſurely the diſſolvable part of lime has as good a title to be ranked in that claſs, as any other ſalt, as it imparts ſuch a ſenſation to the palate, and is diſſolvable in water. It is in the ſolubility itſelf, and not in the degree of it, that the nature of ſalts conſiſts. That it, afterwards, changes into cruſts, and becomes unſoluble, never can affect it in its former ſtate; becauſe it is then altered, and no more the ſame body, though reducible in part to it.

What

WHAT is the nature of this soluble substance? is the next question. Monf. *Du Fay* has endeavoured, in two papers, to make out, that it is, or that it contains a neutral salt; for he never says, that he extracted all the salt from lime that could be got. He seems only to have got the most soluble parts of this substance, or, as Monf. *Malouin* thinks, the crusts, and to have mistaken them for a neutral salt. Monf. *Malouin* says, that the salt of lime is a true neutral salt, consisting of a vitriolic acid and a terrestrial base. This he proves, by telling us, that, on mixing an alkaline salt with lime-water, he got a tartar vitriolatus; on mixing, in the same way, the base of sea salt, he got Glauber's salt; and on adding an inflammable body, he got a sulphur.

BY the preceding experiments, it appears, that no such salt as the tartar vitriolatus is formed from alkaline salts and lime-water; and therefore that gentleman must have been led astray by some foreign admixture in the lime he used. Perhaps when lime-stone is burnt with a coal very much impregnated

impregnated with ſulphur, a ſmall quantity of the vitriolic acid may adhere to it, and produce the effects mentioned by Monſ. *Malouin*. Monſ. *Mackay*, in a ſhort but elegant treatiſe on chymiſtry, has ſhown, by ſome ingenious experiments, that no ſuch acid can exiſt in lime; for he found, that an addition of this acid to different calcarious ſtones, changed their nature to the vitreſcible. The ſame effect happened in *Exp.* 22. Lime in its nature is the very oppoſite of vitreſcible bodies.

When I firſt obſerved a lacteſcency in lime-water, and a ſubſequent precipitation of a powder, and conſidered, that I had only found this effect happen in imperfect neutral ſalts, I was very much inclined, from analogy, to believe, that lime contained ſuch a neutral ſalt. The opinion was very natural. I knew of no method to procure this ſalt, by itſelf, but by diſſolving it in water. There acids make no effervеſcence. This, however, could be no proof, that the ſalt diſſolved in it, was neutral, when I found that a grain of alkaline ſalts

diſſolved

diſſolved in $3\frac{1}{2}$ oz. of common water, made no effervescence with acids. I took the following method therefore to determine its nature.

Exp. 127. I ſkimmed off the ſubtileſt and lighteſt parts of lime diſſolved in water, as I had done in ſome former experiments. Part of this was boiled in water, till it did not taſte of lime, nor made lime-water. Theſe two, and ſome of the cruſts taken from the ſame lime-water, were dried in an equal heat. Six grains of the effete lime required 26 drops of *ſpirit. ſal. marin.* to ſaturate it; 6 gr. of the unboiled, 41 drops; and the ſame quantity of the cruſts, 21 drops. I added 2 tea-ſpoonfuls of water to each powder, before the acid was dropped into it. The firſt was pale, and had a dark oozy ſediment; but the ſecond was yellow, and had no ſediment. It was remarkable, that they all emitted ſtrong acid ſteams during the act of fermentation. The concluſion then from this experiment is very plain, that, allowing 18 drops for the 4 gr. of the unſoluble part in the unboiled lime, which is the proportion that the boiled effete calx took, the 2 remaining ſoluble grains muſt have conſumed 23 drops of the acid; a quantity twice and a half more than the unſoluble part required. The ſoluble part then is ſo far from being a neutral ſalt, that it becomes, by the action of the fire, betwixt two and three times more antacid than the unſoluble part is. The accurate Dr *Alſton* has ſhown, that the cruſts weigh double of the lime diſſolved; and that they get this additional weight from earth, or perhaps ſomewhat elſe, attracted from the water. Twelve grains of cruſts contain ſix grains of lime; and therefore the antacid power of the ſoluble part in theſe cruſts continues the ſame, though it is now changed from a ſaline to a terreſtrial ſubſtance. The cruſts calcined in the fire are burnt to quick-lime, and afford a lime-water. Six grains of this quick-lime required 26 drops of the ſame acid to ſaturate it. The cruſts are found to contain only the ninth part of water; allowing then for the ninth part of water diſpelled, the fire by calcination increaſed the alkaline quality of the whole

cruſts

crufts about a ninth part. But if we confider what a fmall proportion of thefe calcined crufts are foluble in water, we muft allow, that the foluble faline part of thefe crufts have their alkaline quality increafed in a much greater proportion. Thefe experiments fhew evidently the nature of this foluble falt of lime. I would gladly chufe to have more data before I proceed to determine how it becomes unfoluble again; yet there is no harm in attempting a little theory on the data we have, efpecially as we will be fupported by the preceding experiments.

The whole contents got by *Exp.* 125. & 126. from 8 gr. of falt and 6 gills of lime-water, were 15 or 16 gr. In the quantity of lime-water ufed in thefe experiments, there are betwixt 4 and 5 gr. of foluble lime; which, with the 8 of alkaline falt, and 3 more coming partly from the water and partly from the air, juft make out the 15 gr. Whence then comes the precipitated powder? Is it from the lime, or from the alkaline falts? There is a quality in this precipitated powder, which will help us in this queſtion. I found in the courſe of theſe experiments, that the powder precipitated, in boiling, from the pearl ſalts, or, in other words, their earthy baſe, was not a calcarious earth, or could not be turned to quick-lime. The powder precipitated in the foregoing experiments afforded me, at three different trials, lime-water. Hence a plain, and, I think, an undoubted concluſion ariſes, that the precipitation comes from the ſaline part of the lime, and conſiſts moſtly of it.

It appears by one of theſe experiments, N° 126. that the powder precipitated is more than the quantity of ſoluble lime in the lime-water. This appears yet ſtronger from the following

Exp. 128. Six drachms of quick-lime were mixed with eight *Engliſh* pints of water. The lime was well dried in a hot fire. When the lime-water was ſufficiently ſtrong, it was ſtrained off. From this lime-water I precipitated, by the means of alkaline ſalts, 42 gr. of a powder; while the lime, dried

as

as it had been before, and weighed, had loſt only 24 gr.

To four pints of lime-water made with lime of another kind, I added 20 gr. of ſalt of wormwood. The powder precipitated, weighed 19 gr. when gently dried; when kept nearer the fire, it weighed 8 gr. After it had been kept two hours in a ſtrong fire, it weighed but 4 gr. and was then quick-lime. The liquor, when evaporated, gave 19 gr. of an indiſſolvable powder; five or ſix of which muſt have ariſen from the earth of the water. Theſe experiments ſhew us, that the alkaline ſalts loſe ſomething, and that the lime gains ſomething; and that the ſoluble lime has become unſoluble by this addition. If this additional ſubſtance is again diſpelled by the fire, the unſoluble lime becomes ſoluble again. But what this additional ſubſtance is, whether air, an acid, or whatever other principle it is which makes part of the alkaline ſalts, I leave to the determination of experiment. It is probably air, as no air ariſes when alkaline ſalts are added to lime-water, although there

there is a great inteſtine motion. It does not appear to be an alkaline body; for alkaline ſalts turn more ſo by loſing it, as appears by

Exp. 129. Four grains of this cauſtic ſalt deſtroyed 16 gutts of ſpirit of nitre; but 4 gr. of plain alkaline ſalts deſtroyed only 12 gutts. Hence it appears, that the ſubſtance attracted from the alkaline ſalts by the lime is not alkaline. We have already found likewiſe, that the lime by its addition becomes leſs alkaline, in proportion to its bulk, than what it was before.

As there are middle natures which ſeem to join the oppoſite parts of the creation, the terreſtrial and aquatic, the beaſts and birds, the fiſhes and birds, the vegetable and the animal, the mineral and the earthy; lime ſeems to me to be a ſubſtance deſigned by the author of all to connect the ſalts and earths, two ſubſtances that differ widely from one another. It ſometimes exiſts in the one ſhape, and ſometimes in the other. By fire it becomes ſoluble in water, but not

in

in a great degree: by the contact and influence of the air, it becomes an unsoluble earth; still however not so much so, but that it may again be reduced, by a certain degree of heat, to its soluble saline state. Thus much I thought was due to a substance of such general use in the bleachfield, and whose nature and composition was so little understood.

Having once established the cause of hard waters, we are at liberty to use the analytic method, and account, from that cause, for their different effects. With regard to bleaching, they are of the worst consequence. Soap curdled by hard water, has not its natural effects, as the oil and the salts are separated from one another. The same effects will happen in the bleachfield, when the linen is washed with soap. In this case, the latent oils and dirt will not be loosened by the soapy menstruum. This is the reason that hard water will not wash the dirt out of foul linen. But when the hard water was softened by the alkaline salts, it washed as well as the softest water.

Again,

Again, whenever hard water is mixed with the lye, it muſt turn immediately thick. This diſadvantage can be cured, by allowing the lye to ſtand for ſome time, and drawing off the clear liquor. But there is another which cannot: the acid in the hard water joins the alkaline ſalts in the lye, reduces them to a neutral ſtate, and conſequently renders them of no effect in bleaching.

But theſe are not the only diſadvantages of hard water in the bleachfield. Theſe ſalts, thrown on the linen along with the water, muſt penetrate where-ever the water goes. The ſun will ſoon volatilize the acid part; but the earthy will be left in the ſubſtance of the linen, and render it hard and huſky. Nothing but an acid can take that earth out, by reducing it again to a ſaline ſtate. Hence, if more earthy particles are depoſited by the watering, than what are carried off by the ſouring, the cloth muſt not only turn hard, but muſt be tore into holes, and rendered uſeleſs. In this way I imagine it hardens pot-herbs which are boiled in it.

The

The more of theſe ſaline particles are in the water, the more cruſts will be formed in the veſſels in which it is boiled. Hence we find, that all hard waters depoſit much tartarine ſubſtance, while no ſoft water is found to have any ſuch effect. The *Comb* water, as mentioned by Dr *Hales*, is obſerved to be ſofter, and to waſh linen with a leſs quantity of ſoap, than the *Thames* water; while it left no incruſtations in the coffee-houſe boiler, that had been in conſtant uſe for fourteen years.

Bleachers know very well how to avoid hard waters of the third claſs; but having no criterion for thoſe of the ſecond, they muſt often uſe hard water without knowing it to be ſo. I have diſcovered a great degree of hardneſs in ſome of their waters. A method, then, of detecting the ſmalleſt degree, muſt be of conſiderable uſe to them. Alkaline ſalts enjoy this property, and have already been of ſervice in this way. Mr *Samuel Hart* had pitched on a ſpot of ground to make a bleachfield; had examined the ſpring by the known methods; and thought it good. But on trying it by this teſt, which I had informed him of, he diſcovered a conſiderable degree of hardneſs in it, and fixed his bleachfield on another ſpot.

As I thought an examination of different ſprings, in this way, would be of uſe in ſhowing what is the proportion of hard ſprings to ſoft, I deſired that gentleman to examine a variety of them, and give me an account of his trials. As he has done it with great pains and accuracy, I ſhall give the account in his own words.

" I here ſend you an account of the ſe-
" veral trials I have made of waters, by a
" ſolution of ſalts. Theſe trials were gene-
" rally performed between *September* 10.
" and *October* 15. and when the weather
" was dry and fair.

" I ſhall begin with thoſe made on ſome
" ſprings in the neighbourhood of my
" bleachfield at *Ford*, *viz.* on the lands of
" *Vogrie*, *Cheſterhall*, and *Crichton*. The
" firſt ſpring tried was on *Vogrie*, com-
" monly

" monly called *Haly well*; which, on mix-
" ing the ſalts, became immediately turbid,
" and of a bluiſh colour; and, after fifteen
" minutes ſtanding, ſuſpended many white,
" fleecy particles, which in about three
" hours were altogether precipitated, and
" the water remained pure as at firſt.
" Theſe particles were more copious and
" ponderous than what I have obſerved
" from any other water. This I learned
" from the great quantity depoſited, and
" the quick precipitation. I obſerved all a-
" round this ſpring great quantities of lime-
" ſtone, through which I conceived it paſſ-
" ed, and to which I aſcribe its hardneſs.
" I have been further confirmed in this, by
" every trial made of water from lime-
" ſtone; having conſtantly the ſame ap-
" pearance with this now mentioned, in a
" greater or leſſer degree. The following
" experiment will afford a further proof.
" Obſerving near this a great confluence of
" ſprings, which proceeded alſo from lime-
" ſtone, and emptied themſelves into the
" *Tyne*, near the ſame ſpot, and knowing
" the general opinion, that river-water is

 " ſoft,

" ſoft, I determined to try, how far theſe " ſprings affected it with their quality, and " found the river-water here partook of it " in a conſiderable degree. At firſt, on the " mixture of the ſalts, it remained pure, " and continued ſo for about fifteen mi- " nutes, at which time it ſuſpended a blue " cloudy ſubſtance in the middle of the " glaſs. I had not leiſure to attend its fur- " ther progreſs; but no doubt it would have " depoſited a white powder like the other, " though not ſo copious.

" As I had a deſign of fixing my bleach- " field here, induced by the largeneſs of " the ſpring, I was led to a further trial, " by filtering the ſpring through the ſoil, " which is a light brown earth, with a " ſmall mixture of ſand, in hopes of ſoft- " ening it thereby. For which purpoſe I " cauſed two pits to be dug, about three " and a half feet deep, turning the ſpring " into the upper one; which, when filled, " after ſome hours filtered through the " ſoil to the lower pit: from which, two " days after, when the water had ſettled,

" and

"and become pure, I made trial with the "ſalts; and was ſurpriſed to ſee it more "turbid than when taken immediately from "the ſpring. I made repeated trials, and "found it invariably the ſame. I imagine "it had acquired an accretion of ſalts by "paſſing through the ſoil; but this I leave "to you to determine. I made trial of "five other ſprings on *Vogrie*; two of which "proved like this, but not altogether ſo "hard. The other three, which roſe on the "high grounds, were quite ſoft, remaining "pure with the ſalts after many hours "ſtanding. The chief and laſt ſpring "which I tried on *Vogrie*, and which alſo "riſes on the high ground through a bed "of white ſand, is a ſtrong run of water, "known by the name of the *Carſe well.* "This is the ſpring I have choſen to ſup-"ply my bleachfield. After mixing the "ſalts with ſome of this water, it continued "quite pure for three days, the time I "kept it in the glaſs: and as from this "favourable appearance I had reaſon to "think the ſpring very ſoft, I determined, "from other corroborating proofs, to be

"farther

"farther aſſured; for which purpoſe I "made two comparative trials with water "from another ſpring, which I had found "very ſoft, but not altogether ſo much as "this, and might be reckoned next in qua- "lity. This water had remained pure for "above two hours, and then diſcovered a "very ſmall, and rare light cloud, ſcarce "perceptible by the eye, and that only in "a certain light. I took two wine-glaſſes "of each water; in one of each I put ſome "hard white ſoap, pared down, to be diſ- "ſolved; in the other two, ſome galls. I "perceived, that the ſoap in the *Carſe* well "water more readily and equally incorpo- "rated, and the gall produced more ſpee- "dily a ſtronger tincture than in the other "water. This proof determined me.

"THREE ſprings I tried on *Crichton* "ground were of the ſame nature with "*Haly* well, but were longer in diſcolour- "ing, and depoſited a much ſmaller quan- "tity of white powder.

"OF four ſprings I tried on *Cheſterhall*,

"I

" I found three quite ſoft: the other had " ſome ſmall degree of hardneſs; it conti- " nued pure for about an hour and an half; " when it ſuſpended, about half an inch " from the ſurface, a light and rare blue " cloud. In brief, I made trial of about " twenty other ſprings, and found always " the ſmalleſt degree of hardneſs diſcover- " able by the ſalts. The ſeveral waters I " tried, may be ranged into three claſſes, " *viz.* ſuch as continued pure; ſuch as " ſuſpended only a light cloud, after ſtand- " ing ſome hours, and depoſited very little " powder; and, laſtly, ſuch as became " immediately turbid, and diffuſed their " foulneſs through all the water; which " commonly appeared of a milky colour. " I always obſerved thoſe ſprings that pro- " ceeded from ſand and gravel to be ſoft, as " thoſe from lime-ſtone to be hard. I ſhall " only communicate one further trial, with " which I ſhall conclude, and which I on- " ly acquaint you with, as being ſimilar to " the trial made at *Vogrie*, of filtering wa- " ter. On ſeeing a pool of ſtanding water " which had filtered from the *Tyne* near

" *Niſbet*,

" *Nisbet*, through much the same stratum " as at *Vogrie*, I made trial with the salts; " and found, although I had taken it up " quite pure, that it became immediately " very turbid, to much the same degree " with that at *Vogrie*. From whence it " may be observed, that though hard water, " when percolated through sand or gravel, " may be considerably corrected and soft- " ened; yet that every soil, through which " water can penetrate, will not produce this " effect, is evident from the two former " recited experiments. It will then follow, " that sand or gravel is the only soil we " know of that is proper to soften water by " filtering. I take this occasion to return " you my hearty thanks for the favour you " have done me, in communicating the " method of proving water by salts; and " am," *&c.*

Salton, *Dec.* 26. 1753.

Exp. 130. To try what effect hard waters, softened in the preceding way, would have on vegetables, I boiled some pease in soft water, some in hard water, some in the

the hard water ſoftened with alkaline ſalts, and ſome in lime-water. Whenever the peaſe became ſoft in the ſoft water, the whole was removed from the fire. The peaſe in the hard waters, and in the lime-water, were too hard to be eat; but thoſe in the hard water ſoftened, were ſo ſoft, that very few of the peaſe remained entire. Thus tea, malt, *&c.* muſt yield a much ſtronger tincture to ſoftened, than they do to hard water. I poured equal quantities of hard water, and hard water ſoftened, on equal quantities of Bohea tea. The tea was ſtronger with the latter water than with the former.

The antiſeptic quality of hard waters diſcovered by *Exp.* 86. is not taken notice of, ſo far as I remember, by any author except *Celſus*. He has theſe words: *Aqua dura, i. e. ea quæ tarde putreſcit.* According to him, this antiſeptic quality is the characteriſtical mark of hard waters. Let us try ſome experiments with regard to this quality of hard waters.

Exp. 131. *Nov.* 12. An ounce and an half of beef was put into a glaſs with 6 oz. of ſoft water. The ſame quantity of beef was put into another glaſs with the ſame quantity of hard water. The ſame was done in two other glaſſes, with the ſame quantity of fiſh. *Nov.* 22. The fiſh and fleſh in the ſoft waters were putrified, but the others were quite ſound. *Nov.* 27. A piece of each of the latter being roaſted on a fork, were firm and good, but ſomewhat dry. *Dec.* 2. Both ſpoiled. Hence we diſcover, that hard waters have a ſtrong power of preſerving bodies, and may be made uſe of in this way with ſucceſs. Waters three times harder than this, as I have diſcovered thoſe of *Newcaſtle* to be, muſt have a very ſtrong antiſeptic power.

To diſcover the comparative antiſeptic qualities of ſeveral ſubſtances, I made the following trial.

Exp. 132. *Dec.* 1. One ounce of beef was put into a glaſs containing eight ounces of ſoft water. I ſhall call this glaſs N° 1.

N° 2. contained the ſame, with the addition of a ſcruple of common ſea ſalt. N° 3. contained the ſame, with the addition of 2 dr. of the ſame ſea ſalt. N° 4. contained the ſame, with the addition of a ſcruple of the cryſtals of pure ſea ſalt. N° 5. with the addition of 2 dr. of the ſame ſalt. N° 6. contained the ſame quantity of beef, with the ſame quantity of hard water. N° 7. the ſame quantity of beef, and freſh-made lime-water. N° 8. the ſame quantity of beef, and tar-water. *Dec.* 8. N° 4. & 5. began to ſmell putrid, the latter not ſo ſtrong as the former. N° 2. juſt begins to have a little ſmell, but not near ſo much as any of the two former. *Dec.* 16. N° 1. & 3. begin to ſmell. N° 2. very putrid. N° 7. is likewiſe very putrid; and ſtill ſo hard, that it curdled ſoap. N° 6. quite freſh, with a quantity of air-bubbles on the ſurface of the water; which ſhows a beginning change. *Dec.* 26. N° 6. ſmells putrid. N° 8. continues ſtill ſound.

FROM this experiment the following concluſions ariſe. 1*ſt*, This hard water appears to be a ſtronger antiſeptic than lime-water *, but not ſo ſtrong as tar-water. 2*dly*, Two drachms of pure ſea ſalt, diſſolved in 8 oz. of ſoft water, increaſed conſiderably

* There is a difference in opinion with regard to the antiſeptic effects of this ſoluble part of lime, betwixt two gentlemen, to whom the world is much indebted for many ingenious and accurate experiments; I mean Dr *Alſton* and Dr *Pringle*. The former ſays, that the ſoluble part of lime, or lime-water, is antiſeptic; the latter, that it is not. When ſuch ingenious gentlemen, who reaſon and form concluſions from experiment alone, differ in opinion, it muſt be from their viewing things in different circumſtances and ſituations. I am always apt to conclude in ſuch caſes, that both opinions are, in ſome meaſure, true. It is then worth our labour to diſcover by experiment, what difference in the circumſtances of theſe gentlemens experiments gave riſe to ſuch a difference in their concluſions. I am the more particularly called upon to give my opinion in this queſtion, as two letters of mine, which were not deſigned to be made public, have been, by a miſtake, publiſhed in the *Philoſophical Tranſactions*.

Exp. 1. *Dec.* 6. I put two haddocks in an earthen pot, which held 3½ *Engliſh* pints, and filled it with lime-water. One lb. of beef was put in another pot of the ſame bigneſs, and filled with lime-water. After they had ſtood, well corked, eighteen days, the former was quite ſweet, and ſmelt like good lime-water; but the latter had a putrified ſmell, though not very ſtrong. One of the fiſh was partly boiled, and partly dreſſed on the gridiron; and it eat both ways very well, though a little ſoft, and retaining ſomewhat ſiderably its ſeptic power. 3*dly*, Two drachms of common ſalt preſerved the fleſh twice as long as the ſame quantity of pure ſalt. This muſt have been owing to the mixture

ſomewhat of the taſte of lime-water. The fleſh was a little tainted, and of a whitiſh colour, when prepared in the ſame way. Freſh lime-water was put on both, the former being poured off. When they had ſtood four weeks longer, the fiſh was quite freſh, and appeared ſomewhat ſwelled; but the fleſh was very putrid. When the fiſh was put into boiling water, it diſſolved immediately into a gelly. Lime-water appears, then, to deſtroy the cohering principle in fiſh.

Exp. 2. *March* 26. I hung about 3 oz. of fleſh and a ſmall haddock in the open air in the kitchen; put the ſame quantities of theſe two ſubſtances in two different pots filled with common water, ordering the water to be changed every day; and the ſame quantities of the ſame ſubſtances into two pots, ſuch as I mentioned in the former experiment. *April* 2. The fiſh and fleſh in the air were dried; the fiſh had no bad ſmell, but the fleſh was tainted: the fiſh and fleſh in common water ſmelt ſtrong: the fiſh in the lime-water was ſweet, but the fleſh ſmelt as ſtrong as that in the common water.

Exp. 3. *May* 18. Into four different glaſſes, each of which held 3 gills of lime-water, I put four different ſubſtances; into the firſt 1 oz. of beef; into the ſecond the ſame of lamb; into the third the ſame of mutton; into the fourth the ſame of whiting; and corked them. 26. The glaſs containing the lamb ſtank much; the beef and mutton were a little corrupted; but the fiſh quite ſound. *June* 2. The ture of the bittern with the former; and ſhews, that theſe two ſalts have very different effects.

The fiſh was ſtill ſweet, but all the fleſh ſmelt very ſtrong: the lime-water in which the beef was, appeared of a high red colour; that in which the mutton was, appeared leſs red; that with the lamb was but gently tinctured; that with the fiſh was ſtill white. The lamb ſeemed moſt putrid. *June* 7. Fiſh ſound. 26. Fiſh was putrid. *Aug.* 6. The fiſh ſmelt more offenſively than any of the former.

Would not any one be apt to conclude from theſe three experiments, that lime-water preſerved fiſh, and not fleſh? I did ſo; but was ſoon convinced of my error by the following experiment.

Exp. 4. *May* 19. Into an earthen pot, holding 3½ *Engliſh* pints of common water, I put 1½ oz. of mutton; into another, holding the ſame quantity of lime-water, I put the ſame quantity of mutton. 26. The mutton in common water was putrid, but that in the lime-water was not. *June* 7. Fleſh in the lime-water ſtill ſweet. 26. Still ſound. *Aug.* 6. Was a little putrid.

It appears, then, from theſe experiments, that lime-water is antiſeptic, with regard to fleſh, when uſed in a certain quantity, and when the pieces of fleſh are ſo ſmall that the lime-water can eaſily penetrate them; that lime-water is antiſeptic, with regard to fiſh, in a greater degree, probably becauſe it more eaſily penetrates fiſh, from its leſs firm texture; and that the difference of theſe two ingenious gentlemens concluſions aroſe, probably, from their uſing, in their experiments, different quantities of fleſh and lime-water.

We could easily account for all the bad effects of hard water on the human body; and show, that, by the separation of the acid from the terrestrial base, which must happen in the body, several diseases must arise; such as, the stone and gravel, rheumatism, colics, gout, and many others; but this is not the proper place. These unhealthful effects of hard water may be easily prevented, by mixing alkaline salts with it. The hard water I have used in these experiments, takes about 1 dr. to one *English* pint: A very small quantity to produce so excellent an effect. The milky water must be allowed to stand till it becomes clear, before it is used for drink.

To discover whether the effect of hardening vegetables depended on the acid, or on the earthy particles left in the substance, I tried the following experiment.

Exp. 133. Four different parcels of green pease were boiled, for the same time, in the same degree of heat, in four different waters; *viz.* soft water; hard water; artificial

ficial hard water, made with the abſorbent baſe of the hard water, and the oil of vitriol; and ſome ſoft water, with as many drops of the ſpirit of nitre in it as I thought was equal to the acid of the hard water. When the peaſe of the ſoft water were enough boiled for eating, I took out the whole. The peaſe in the hard water were ſo hard, that they could not be eaten; and at the ſame time not ſo green as thoſe in the ſoft water. Thoſe in the artificial hard water were like the former. Thoſe in the water with the nitrous acid did not taſte acid, were lighter-coloured, and ſofter than the reſt; their ſkins were moſtly broke. The earth was found before not to harden water, and the acid is now. Hence it muſt ariſe from the ſaline particles entering compounded, and the acid leaving the earthy behind; which, from the volability of the former, muſt ſoon happen. Hard water, though it does not make vegetables greener, as is generally thought; yet as it keeps them longer hard, it keeps them longer green.

THIS

THIS method which we have discover-ed * of softening hard waters, is easy, expeditious, and cheap; qualities absolutely necessary to render it useful to the public. It is easy, as the most ignorant can do it; expeditious, as it becomes fit for all family-uses immediately, and for drinking in half an hour; and cheap, as the material costs but a mere trifle; nay may be prepared by any person. By this change, the hard water not only becomes fit for all the common uses of life, but as beneficial as it was before hurtful to the health of man. Lord *Verulam* had so high an opinion of the salutary effects of nitre, that, as we are told, he used to mix it with all the water he drank. Hard water, when corrected by al-

* I have discovered, since these papers were in the press, that Dr *Shaw*, in his chymical discourses, has given an imperfect hint of this quality of alkaline salts. He says, that hard water becomes softer by an addition of alkaline salts. I call this hint imperfect, because hard waters may be made softer, and yet continue hard, as they admit of various degrees of hardness. The foregoing experiments show, that all kinds of hard waters are altogether softened by alkaline salts. Nor does the Doctor inform us of the manner of doing it, or reasons on which it depends, or qualities of the water after it is softened.

kaline ſalts, turns into ſoft water impregnated with nitre. I may venture to affirm, that no other material can ever be found capable of ſoftening hard water: and tho' one was diſcovered endued with the ſame property, it could not be of the ſame uſe to mankind, as there is none, alkaline ſalts excepted, to be had every where. A particular ſubſtance or plant was only to be found in particular places, but this material is to be got where-ever plants grow. So kind is the general parent of nature, that he has provided a remedy, every where to be found, for ſo common an evil; but, at the ſame time, has left the diſcovery to our own induſtry.

How much we ſtood in need of ſuch a diſcovery, moſt great towns, eſpecially thoſe on the ſea-coaſt, nay the greateſt part of ſome counties, can teſtify. *Newcaſtle* is a remarkable inſtance of this diſtreſs. In all the pants or pipes there, two excepted, the water is hard; and to ſuch a degree, that it is three times more ſo than the hard water which I have examined. The nitrous acid,

acid, joined to an abſorbent baſe, is the cauſe. The precipitation from theſe waters, by the means of alkaline ſalts, was in ſo great plenty, that the fourth part of the glaſs was covered with it, and amazed not a little thoſe who made uſe of the water. There the old and infirm complain, that theſe hard waters give them a ſourneſs of the ſtomach, and colics.

As the ſtrength of different alkaline ſalts differ, and as ſome hard waters are much harder than others, nay the ſame water harder in dry than in wet weather, ſome eaſy and certain general rule of ſoftening all hard waters is neceſſary; the following appears to me the beſt. Let a certain quantity of alkaline ſalt be diſſolved in a certain quantity of ſoft water. Into a certain quantity of hard water in a glaſs pour in the ſolution gradually, ſo long as the milky colour is on the increaſe. When that is at the height, let the water ſtand till it becomes pellucid. Try it again with a few drops of the ſolution; if no whiteneſs ariſes in the water, it is then ſoft; if there does, go on drop by drop until no more white clouds arife. By this means it is known what quantity of falts is neceffary to foften that quantity of water; and, confequently, how much any given quantity of water will require.

Quær 1. Is not hard water more nourifhing for vegetables than foft water? I imagine, that the falt of vegetables enters their veffels in fuch a form as this falt of hard waters. The falt likewife feems to be of the nitrous kind; which we think the nourifhment of plants. As this query is oppofite to the general opinion, (for no gardener will make ufe of hard water, if he can fhun it), I watered fome plants with it, and thought that they grew better than thofe which were watered with foft water.

Quær. 2. May not hard water be proper for fome particular conftitutions, and for fome particular difeafes, fuch as putrid fevers, *&c.*? The antifeptic quality of thefe waters would feem to be ufeful to putrefcent habits.

Quær.

Quær. 3. Do these hard waters supply the air with a nitrous acid? We have discovered by these experiments, that the nitrous acid of this water is easily separated, by a boiling heat, from its absorbent base; and that it arises even by a gentle distillation. We find likewise, that all hard waters deposit more or less of an absorbent earth. Hence we may reasonably conclude, that there is a real nitrous acid, distinct from the vitriolic acid, communicated by these hard waters, to the air; and that from the former, and not from the latter, as chymists have imagined, nitre is generated. This is further confirmed by an observation of the learned Dr *Plummer*, who says, that he has oftener observed nitre produced or regenerated, than vitriolated tartar, from an alkaline lixive long exposed to the air.

Quær. 4. Is not hard water more proper to be carried to sea than soft water, as it appears to resist putrefaction very powerfully?

Quær. 5. Is not the cause of hard and petrifying

petrifying waters the ſame? and do not they differ only in degree? When the ſaline ſubſtance impregnates the water very ſtrongly, the earth, depoſited in the interſtices of any ſubſtance, muſt be continually on the increaſe, till at laſt the ſubſtance becomes a ſtone. This I imagine is the way that all petrifying waters act, and accounts very naturally for their effects.

Quær. 6. Do not the brewers, in great cities, who generally make uſe of hard water, loſe a very great part of the ſubſtance of their malt, as we have found hard water very unfit for drawing a tincture from any vegetable? Will not hard water, ſoftened in this way, make ale of a much greater ſtrength from the ſame quantity of malt? and what effect will nitre have on ale?

Quær. 7. Do hard waters contribute to ſterility, as *Hippocrates* aſſerts?

Quær. 8. Muſt not hard waters have in general a very bad effect on digeſtion, as they tend

tend to keep all bodies in their natural ſound ſtate?

Quær. 9. How happens it that *Briſtol* water is reckoned ſo exceedingly ſoft, inſomuch that it is thought to come from chalk, when it is really a hard water? What acid does it contain? Are not its effects in conſumptive hectic caſes owing to this imperfect neutral ſalt?

Quær. 10. Is not the effect of hard water in turning pewter black, owing to a ſolution of the metal by the acid?

Quær. 11. Are all waters hard which lie at a conſiderable depth below the ſurface of the earth? and is it not neceſſary that theſe ſhould have ſome particles in their compoſition of an antiſeptic nature, to reſiſt the effects of heat and ſtagnation, to which they are liable?

SECT.

SECT. III.

The effects of ſteel and coal waters on cloth, and the cure.

HARDNESS is not the only pernicious quality in waters which the bleacher has to ſhun. All impregnations with bodies ſuſpended in that fluid, whether they are earthy, ſaline, or metallic, retard, nay often entirely ſtopt the whitening of cloth. There are two ſpecies of waters particularly deſtructive in this art, I mean vitriolic or chalybeate waters, and coal waters. As theſe are very common in this country, the bleacher ought to be more upon his guard againſt them. It therefore becomes neceſſary for him to be able to diſtinguiſh them from other waters, and to remove their bad effects when they happen to be uſed.

ALL ſteel waters, whether the iron be diſſolved by an acid or not, depoſitate a red ſubſtance, called *ochre*. This is to be obſerved in the channel where theſe waters run.

run. It is moſtly compoſed of the particles of iron precipitated to the bottom, with a ſmall addition of whatever ſaline ſubſtance exiſts in the water. Theſe particles are depoſited, continually, on the ſurface of the cloth, when watered with a chalybeate water, and effectually ſtop all further progreſs in whiteneſs. This happened to a poor woman, who watered ſome webs ſhe was bleaching from a ſpring near her own houſe. To her great ſurpriſe they turned redder and redder every day. Not being able to account for this effect in a natural way, or to remove that colour, ſhe imputed it to witchcraft, blamed the neighbour ſhe hated moſt, and ſold them for a trifle. That water was afterwards diſcovered to be a mineral ſpring.

Had ſhe conſulted a chymiſt, he would have ſhown her a method of diſſolving the charm. Water, with the addition of a ſmall proportion of oil of vitriol, would have carried off the ochrey matter. I watered ſome white linen with the *Hartfield* ſpaw water, till it had acquired a pretty ſtrong red colour. This linen ſteeped in water gently acidulated with vitriol, in a few hours, came out white again. I am not ſure, however, whether all ochres can be diſſolved by acids. I have tried ſome which were not. Againſt theſe I know no remedy.

It is therefore of great conſequence to the bleacher, that he ſhould be able to diſtinguiſh theſe waters, when he meets them, from others, in order to ſhun them in the ſituation of his bleachfield. The characteriſtical mark of theſe waters, is, That they turn purple or black with galls, green tea, or the leaves or bark of the oak. If this effect happens, on the mixture of theſe bodies, the water is improper for bleaching.

There is an ochrey ſubſtance, like the former in appearance, which has not yet, ſo far as I know, undergone any examination; I mean that of coal waters. Whenever they are uſed in the watering of cloth, they leave a yellow colour. That we may be able to remove theſe particles when lying on the ſurface of cloth, it becomes neceſſary to examine

amine their nature, and to diſcover their proper ſolvent.

THIS examination will be attended with another advantage. This ochrey ſubſtance is reckoned one of the ſureſt marks of coal. But how can it be depended on, when many waters, which do not come from coal, have a like appearance, and when the diſtinguiſhing properties of theſe ſimilar ſubſtances are not aſcertained? A chymical examination is the only method to fix theſe. I have elſewhere examined the ochre of mineral waters, and diſcovered its properties and nature *. I ſhall endeavour, here, to do the ſame with that of coal waters. The ochre I made uſe of was taken up carefully from the channel of a coal-level, and had been kept by me near a year.

Exp. 134. The ochre of coal waters has no particular taſte, and feels in the mouth gritty, and not fat, as that of mineral waters does.

* Eſſay on *Dunſe* ſpaw.

When put on a red-hot iron, it ſparkles, but emits no ſulphureous or acid ſteams.

Half a drachm of it mixed with warm water, and the liquor ſtrained and evaporated, gave a ſmall quantity of a ſaline reſiduum, which liquified in the air, taſted ſharp, and rendered half an ounce of water reddiſh and hard. Paper dipped in this liquor, burnt like a match, and diſcovered the ſalt to be nitrous.

It efferveſced with water acidulated with oil of vitriol. The liquor, with an addition of galls, turned into an ink. When thrown on melted nitre, it ſparkled, but did not deflagrate.

The magnet has no effect on it before calcination. Twenty grains, calcined for two hours in a fire, were reduced to 14, and were all attracted by the magnet.

Two drachms and a half were diſtilled, and gave me about $1\frac{1}{2}$ dr. of a liquor, which turned ſyrup of violets green, efferveſced with

with mineral and vegetable acids, and had the ſmell of ſpirit of hartſhorn.

From this experiment, then, we diſcover the nature and properties of coal ochre. We ſee that it is compounded of iron, and a neutral ſalt, like that of all hard waters. We obſerve, likewiſe, its proper ſolvent, oil of vitriol diluted with water; and that the ſame mixture which removes the ochre of mineral waters, will remove this. But what is perhaps of greater moment, its properties appear to be very different from thoſe of other ochres. If ſuch a ſubſtance was preſented to me, I think I could tell whether it came from coal or not.

S E C T. IV.

Some conſiderations with regard to the further improvement of our linen manufacture.

THE demand for manufactures is in proportion to their goodneſs and cheapneſs. That country which affords the

the beſt, and at the loweſt prices, will find the readieſt market. To theſe two points muſt every deſigned improvement tend. For that end the foregoing experiments were calculated. I have endeavoured, by their aſſiſtance, to ſhow where the common practice was right, and where wrong; to propoſe ſome improvements in it; to introduce new materials made at home; and to ſhorten the time of ſome operations conſiderably; to explain the principles upon which the whole is conducted; and, in ſhort, to make the bleachers underſtand their art thoroughly; the only method to make them operate better and cheaper, without diminiſhing their gains.

I am very ſenſible how difficult a thing it is to alter the eſtabliſhed opinions of mankind; and how much more difficult to alter their practice. As the experiments in this diſquiſition have been many, and the reaſonings few, the author can never expect to paſs for a theoriſt: but conſidering the prejudices of mankind, the trouble of making proper trials, and the qualities requi-

ſite

ſite for ſuch a work, their effects in the bleachfield muſt be but very ſlow. It is reaſonable they ſhould be ſo. Alterations in the common practice of the arts are too dangerous, both for the public and particulars, to be haſtily gone into. But yet when Experience points the way, it is unpardonable to neglect its advice.

Having now ſecured the moſt important and dangerous part of our linen manufacture, let us caſt our eyes on the other branches, and conſider if there be not room likewiſe for further improvement in theſe. Every manufacturing country ought, if poſſible, to have the materials of their manufacture produced within the country; that it may not depend upon foreigners, nay perhaps upon their rivals in trade, whether they ſhall have a manufacture or not. The Honourable board of truſtees for fiſheries and manufactures have given all attention to this point; and, by proper regulations and premiums, have endeavoured to encourage the growth of flax at home: but all they have done has been yet attended with little ſucceſs;

ceſs; and I am afraid, if ſome ſpeedy aſſiſtance is not given, things will rather turn worſe than better. Complaints have been made by manufacturers, that our home flax is not ſo good as the foreign. I am of opinion, that it is more owing to our want of ſkill in watering of it, than to our ſoil, or methods of managing it there. We have all kinds of grounds, and excellent rules laid down for their culture: but the proceſs of watering ſeems not yet thoroughly underſtood; and the practice, as carried on by the commonalty all over the country, is moſt deſtructive to the flax. As it is of ſuch importance to our manufacture, and as it is a chymical operation, we think it deſerves our conſideration, in a treatiſe deſigned to improve our manufacture by the aſſiſtance of chymiſtry.

Whoever will attend to what paſſes during the ſteeping of lint in ſtanding water, and during fair weather, or will make the experiment in the houſe, muſt find it attended with the following circumſtances. On the ſecond or third day, if the weather is warm, a great many air-bubbles arise to the surface of the water, and by degrees a scum or pellicle gathers there, which is full of these air-bubbles. The water gains a small degree of heat, and a corrupted smell. If the flax is allowed to lie too long, it turns corrupted, black, and loses all tenacity. These effects evidently show, that the process of steeping flax is the process of putrefaction carried on to a certain length.

EVERY one knows, that the intention of steeping is to loosen the harl or bark of the flax from the bun or woody part of that plant; and that it is to be accomplished by a solution of the oil, or mucilaginous substance, which makes them cohere. Putrefaction is the instrument at present employed to attain that end. The intestine motion raised by it, disunites, attenuates, and dissolves that vegetable glue, and renders it miscible with water. The great art is to know when that is done. If the flax is allowed to lie any longer in the water, that oil which unites the solid particles of the harl is diſſolved, and the fibres loſe all ſtrength.

The time which flax muſt lie in the water, is to be meaſured, then, entirely by the quickneſs or ſlowneſs of the putrefaction. As this depends on the concurrence of many circumſtances, *viz.* the nature of the flax, its quantity, the heat of the weather, length of the nights, nature and quantity of the water, and many others, it is impoſſible to fix a certain time. The flax, when ſufficiently watered, acquires a ſlippery oilineſs on its ſkin, owing to a ſolution of that mucilage mentioned before: but *Pliny*'s rule is ſtill the moſt certain, *Maceratos indicio eſt membrana laxatior, lib.* 19. The flax ought therefore to be inſpected, after the fourth day, every ſix hours; and when the bun appears brittle, and the harl ſeparates from it, the flax ought to be immediately taken out. Nor ought we to wait, as is judiciouſly obſerved in the *Dublin* eſſays, till the ſeparation becomes too eaſy; but leave that to be completed by the dews and warmth when expoſed on the graſs. As the danger is great in allowing it to lie too long, ſo there are ſeveral bad effects ariſing from taking it out too ſoon. The black bars which run acroſs the linen, and are ſo difficult to remove in bleaching, are none of the leaſt. To whiten theſe, the reſt of the cloth is often damaged. When flax has been kept ſomewhat too long in the water, none of theſe black bars are to be ſeen. They increaſe in proportion to the deficiency or failure in that degree of putrefaction neceſſary to ſteeping. I am told by an experienced bleacher, that he prevents, in a great meaſure, theſe black bars, by ſouring the yarn after it has been boiled with aſhes.

When we once underſtand how this proceſs is carried on by nature, we will ſoon ſee what is the buſineſs of art. We muſt regulate the proceſs of putrefaction ſo that it does not meet with too great obſtacles to ſtop it, nor be allowed to go on too rapidly. The latter muſt ſeldom be the caſe in this climate; but the former often. Running water muſt appear at firſt ſight entirely improper for ſteeping lint, as the corrupted

 particles

particles are continually carried off. Springs have the ſame fault in a leſſer degree. Nothing promotes putrefaction ſo much as quietneſs and heat; nothing ſtops it more than agitation and cold. Steeping ought always then to be performed in a place as much ſheltered from the winds, and in a ſeaſon when it will have as much heat as poſſible. I would chuſe that the water ſhould not be too ſhallow, that it may not be too ſuddenly affected by the coldneſs of the night, or other changes of weather. The more uniform the heat of the water is, the more ſafe the proceſs will be. Ponds made at the ſides of lakes or of rivers, not too near their ſource, appear in general to be the moſt eligible places. If the proceſs goes on too ſlow, on account of the nature of the lint, water, or weather, chymiſtry teaches us how to quicken it. The putrid fermentation can be checked or quickened, as well as the vinous. As yeaſt increaſes the latter, ſo do all putrid bodies the former. Some putrid vegetable ſubſtance mixed with the water, would anſwer this purpoſe.

FROM what has been ſaid, we may eaſily account for the practice of the *Dutch*, who lay the dirt and mire found at the bottom of their ſteeping ponds, on the ſurface of the flax after it is laid in the water. When that corruptible matter lies there, it communicates putrefaction to the water more equally than if it lay at the bottom. We likewiſe ſee the reaſon why thoſe who underſtand the ſteeping of flax, never allow it to touch the ground: for when that happens, the flax which lies there, bearing the preſſure of all above it, putrifies ſooner and faſter than what lies above. We may likewiſe account for another fact, that flax muſt lie four or five months in moſs-water before it is ſufficiently watered. Moſs-water, ſo far from corrupting, preſerves even animal bodies from corruption. This water is too much uſed in this country, and highly prejudicial to the flax.

BUT, of all waters, none ſeem ſo bad as thoſe which have a conſiderable degree of hardneſs, becauſe theſe have already ſhown themſelves to be almoſt incorruptible.

Common

Common practice had diſcovered this without knowing the reaſon of it, and therefore hard waters are marked as improper. If they muſt be uſed, we are ordered to fill the ponds, and expoſe the water to the ſun for ſome weeks *. But it has appeared from undoubted experiments, that there are many degrees of hardneſs, which have not hitherto been diſcoverable; and that expoſition to the ſun is not a remedy againſt hard waters. We have diſcovered a criterion for the former, by which we are able to perceive the ſmalleſt degrees of hardneſs; and a cure for the latter, in caſe we are neceſſitated to uſe it. Let us then, by experiment, try the effects of hard water on flax; and ſee if theſe effects can be removed, by being ſoftened in the way I have deſcribed.

Exp. 135. *Sept.* 11. I ſteeped equal quantities of flax in three different kinds of waters, *viz.* hard water, the ſame ſoftened with alkaline ſalts, and ſoft water. The laſt, though it broke ſoap, and was the ſoft-

* Vid. *Dublin* Eſſays.

eſt, in the place where I tried this experiment, was not ſo ſoft as I could have wiſhed. On the 14th they all had a ſcum, with air-bubbles on their ſurface; but the hard water had the leaſt. On the 17th all the waters had a putrid ſmell; the hard and ſoft waters were pale-coloured, but the hard water ſoftened was of a high colour. On adding ſome alkaline ſalts to a cupful of the ſoft water, it turned almoſt as high in the colour as the former. The flax in the ſoftened water, was the only one of the three whoſe ſkin felt oily. Some of each parcel being dried, that taken out of the ſoftened water was of a higher colour than the other two, and was rather too much watered; that from the ſoft water not ſufficiently; that from the hard water no better than when put in. On the 20th, the flax in the ſoft water appeared to be completely watered. On the 24th, the flax in the hard water was almoſt watered, but its ſkin did not feel ſlippery as the others had done. This experiment ſhows the bad effects of hard water in ſteeping flax, and at the ſame time how to cure theſe.

THE

The proceſs of putrefaction, by which the preſent method of ſteeping flax is carried on, admits of too great variety with regard to weather and water, and is too dangerous to be managed with ſafety by the commonalty. It would be much for our advantage, and I have often thought it poſſible, to diſcover a ſafer method than that at preſent uſed. I was inclined to think, that the addition of alkaline ſalts to the water might anſwer that purpoſe. For the qualities requiſite in ſuch a body, were to reſiſt putrefaction, and diſſolve the oil betwixt the harl and the bun; and theſe two qualities appeared to me to be inherent in theſe ſalts. As I never make any uſe of theory, but to lead me to experiment, I made the following.

Exp. 136. *Sept.* 26. Some flax was ſteeped in ſoft water; an equal parcel in the ſame quantity of water, with the addition of 2 dr. of pearl ſalts to each *Engliſh* pint and a half; another parcel in the ſame quantity of water, with 1 oz. inſtead of 2 dr. *Oct.* 2. The firſt parcel was ſufficiently ſteeped; the

ſecond

ſecond not fit for taking out; and the third ſtill further removed from that ſtate. *Oct.* 7. The ſecond was finiſhed; but when dried, ſeemed very brittle. The third was no better than when put in.

The next thing to the relation of ſucceſsful experiments, is the relation of unſucceſsful ones. Even theſe are attended with many advantages. However unſucceſsful the laſt has been, I do not yet deſpair of finding out ſome body which will anſwer all the ends of putrefaction without the danger of it. In the mean time, it appears highly neceſſary, that ſteeping ſhould be made a buſineſs diſtinct from the raiſing of flax. In *Holland* it is managed by lint-dreſſers, who buy the flax ſtanding on the ground.

I am apt to think, that the great ſtop to the progreſs of our linen manufacture lies in this very point, the ſteeping of flax. Our farmers, by the wiſe regulations of the board of Truſtees, ſeem to underſtand the culture of flax well enough; and, notwithſtanding ſome ſmall diſadvantages from the nature of our climate, would raiſe it in ſufficient quantity, and find their profit in it, if they could diſpoſe of it, before ſteeping, to a ſet of people who underſtood that proceſs. The farmer is at preſent unwilling to deal in it, becauſe, though he raiſes flax of the beſt kind, it is generally ſpoiled in the watering, and becomes of leſs value than the foreign. The ſteeping and dreſſing of flax ought, therefore, to be made a diſtinct buſineſs; and, as it is the branch of our linen manufacture leaſt underſtood, ſhould be moſt encouraged. All premiums in arts and manufactures, ought to be directed to thoſe branches which are leaſt underſtood. It would ſeem at firſt neceſſary to bring over a ſet of *Dutch* lint-dreſſers, by proper encouragement, and that premiums ſhould be given to thoſe lint-dreſſers who produced the greateſt quantities of the beſt dreſſed *Scots* lint.

From what I have ſaid on bleaching, it appears, that cloth, from its hard and firm texture, reſiſts for a long time the entrance of of thoſe materials which are to whiten it. But the lint and yarn are not ſubject to this objection. Would it not, then, ſave a great deal of trouble, expence, and hazard, if theſe were bleached, at leaſt in part, before they went into the loom? I am afraid it would not be ſo eaſy to manage the lint, as it is ſo light a body; but as for the yarn, I can diſcover no material objection againſt it. One I have heard, and that is, The yarn would become too oozy. But that fault, I imagine, could be corrected by the weaving, and the gentle bleaching which would afterwards be neceſſary.

It is the opinion of all the bleachers, that the cloth of this country is of too thick a fabric, owing to the coarſeneſs of the woof. I agree with them. That ſpecies of cloth requires ſo many buckings before the ſalts can penetrate into the inner parts, that the external threads are too often deſtroyed before the internal are whitened. On the contrary, the thinneſs of the oppoſite ſpecies of cloths is more than counterbalanced by the preſervation of its fabric in the bleach-

 field.

field. Beſides, the expence of bleaching thin cloth is not near ſo great as that of bleaching thick. The former retain their colour better, and appear finer at the ſame price; which will always recommend them to the merchant.

THERE is nothing promotes an art faſter than the communication of thoſe who practiſe it; nothing retards it more than a ſelfiſh ſpirit of keeping all a ſecret. It is by a gradual progreſs, where one refines upon the inventions of another, and not by the endeavours of a ſingle perſon, that arts arrive at perfection. I cannot, then, but recommend to the Honourable Board of Truſtees, a ſcheme of Mr *John Chryſtie*. He not only has made many advances himſelf in this art, but is deſirous that others ſhould do the ſame. He propoſes, that every bleacher, eſpecially thoſe who have got, or expect any premium from the Truſtees, ſhould annually deliver an exact account of his method of bleaching. If this propoſal took place, ſeveral faults would be obſerved and corrected; ſeveral advantages gained; the

the bleachers made more knowing, as one may excel in a particular branch, who is very deficient in all the reſt; a complete hiſtory of the practice made out; and the art itſelf arrive at perfection. Let thoſe who ſhelter themſelves under the appearance of ſecrets, know, that ignorance always does the ſame.

I know nothing that muſt have been of greater advantage to the linen manufacture of *Ireland*, than their linen hall. The manufacturer brings his cloth there, is provided by the public with a proper apartment for his goods, and is ſure of a market in a few days. The public, having the cloth under its eye, is aſſured of its goodneſs, and proves a continual check to private frauds. The foreign merchant, knowing where he can ſupply himſelf at once, is under no neceſſity of acting by commiſſion at a diſtance, or if he ſhould come, of dealing with retailers; but reſorts to this market, and makes his bargain with the manufacturer himſelf. Theſe conſiderations make their cloth go better and cheaper to foreign markets, and are alone ſufficient to overpower

any

any nation who does not follow ſuch a prudent conduct.

To you, Gentlemen, who are poſſeſſed of landed eſtates, I muſt now apply myſelf. You are, or may be, the great promoters and directors of induſtry among your tenants and dependents. It is from you that the commonalty will take that bias of mind, which makes them uſeful or uſeleſs ſervants of the public. It is in your power, by procuring materials at the cheapeſt rates; by encouraging the induſtrious, and diſcouraging the ſlothful; by ſmall premiums to excite emulation; by taking the rents of your houſes in manufactured goods, rather than money; by inſtituting markets at proper times for the ſale of yarn; and by many other methods, to raiſe a ſpirit of labour and induſtry.

There is nothing ſeems more to be deſired, than a change in the education of the young people of both ſexes. While it continues on the preſent plan, of educating them, at a public ſchool, to reading, writing, and compting, I have no hopes of ſeeing them very induſtrious. That habit can only be got when young. By the preſent plan they are a burden on their parents till they are fully grown up, while they might be acquiring ſtrong habits of induſtry, earning their own bread, and adding to the wealth of their country. The conſequences of this education are viſible, after the men have applied to day-labour; for they know not how to turn to any account four or five hours every night during the winter, too much time to be loſt, and which might yield a conſiderable advantage, if they had been taught ſpinning, or any other ſpecies of manufacture. It is well if this turn to ſpeculative knowledge, which they have got, is attended with no worſe conſequences. It would be for the advantage of this country, nay for the real happineſs of its inhabitants, that we had ſpinning-miſtreſſes, as well as ſchoolmaſters, in every pariſh.

Necessity is allowed to be the greateſt ſpur to induſtry. People work not for pleaſure, but for a livelihood. When that is eaſily procured, as in cheap years, induſtry abates;

abates; when with greater difficulty, as in dear years, induſtry increaſes. I have often thought, that thoſe ſorry cloaths, houſes, and meals, to which our commonalty has been accuſtomed, inſtead of being aſſiſtants, as they may appear at firſt ſight, were great enemies to our growing manufactures. Our people work but in proportion to their demands; and if at any time they have more money than ſupplies them, it is ſpent in drink. It is only the gentlemen who can bring about a change in theſe articles. Till I can ſee a greater degree of refinement; till I can hear that our commonalty are poſſeſſed of ſtronger deſires with regard to thoſe conveniencies of life than they are at preſent, I ſhall expect no change in their activity.

It is to the government we muſt chiefly be indebted for the progreſs of our linen manufacture. It is there alone that eaſe can be had from the duties on ſoap and aſhes, which bear hard on our manufacture. It is there alone that a conſtant market can be provided for us, by encouraging the exportation

portation of our own, and discouraging that of foreign cloth; and by other methods which the wisdom of the nation shall think proper. Without some proper and speedy encouragement of this kind, our manufacture must soon decline; perhaps it does so at present. No industry on our side can possibly counterbalance those heavy taxes which we pay on all the necessaries of life, and which our rivals in trade know nothing of. If we are obliged to give up the linen, we must endeavour to cultivate the woollen manufacture, whose seeds are already sown in this country.

I look on it as a loss to *Great Britain*, and to arts and manufactures, that we have no academy instituted by public authority, and at the public charge, to which the care and further progress of these might be intrusted; and whose members, secured in a decent livelihood, might follow the natural bent of their genius; and hear, with safety, the enthusiastic voice of Fame. What a trifling sum to *France* is the yearly expence of the Academy of Sciences! and yet of what benefit has it been to the arts and manufactures of that country! Their ſuperiority in many arts, and eſpecially in dying, has been entirely owing to the labours of this ſociety. *Lewis* XIV. in whoſe reign this academy was inſtituted, has gained victories by it over thoſe whom his ſword could not ſubdue.

F I N I S.